Assessing the livelihood resilience to change in the Sundarban mangrove system due to climate change

by

Md. Shibly Sadik

MASTER OF SCIENCE IN WATER RESOURCES DEVELOPMENT

Institute of Water and Flood Management
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

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BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Institute of Water and Flood Management

The thesis titled 'Assessing the livelihood resilience to change in the Sundarban mangrove system due to climate change' submitted by Md. Shibly Sadik, Roll No. M10072809F, Session: October 2007, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Master of Science in Water Resources Development in July 25, 2009.

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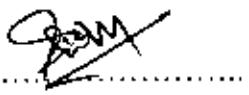

Md. Shibly Sadik

Roll No. M10072809F

Session: October, 2007

Dedicated to My

Heavenly Father

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ABSTRACT

The Sundarban mangrove forest is a biogenic coast. The impact of human induced climate change is being observed there. The state of the Sundarban ecosystem is changing and coupled with poverty, it makes the livelihood dependent on it more vulnerable. Resilience analysis of livelihood groups offers elements of adaptive strategy to the policy makers for mitigating the vulnerabilities.

The study was aimed to assess resilience of Sundarban dependent livelihood groups to climate change induced salinity intrusion after developing an indicator framework through participatory approach Shared learning dialogue and sustainable livelihood assessment are the two key methods followed in this study. Each step of the study i.e., identifying livelihood groups, analysis of the impact of salinity intrusion on Sundarban dependent livelihood, and development of indicator framework for assessing livelihood resilience, was preliminarily conceptualized based on reviewing literatures, and was refined through SLD later.

In this study a resilience framework consisting of 24 indicators has been developed to assess the resilience of Sundarban dependent livelihood groups. The indicators were selected from three dimensions; i) productivity, ii) sustainability and iii) risk that describe both the dynamic and static attributes of livelihood resilience. The framework was made operational by developing word scenarios for each indicator.

Finally the indicator framework was employed to assess livelihood resilience of the Bawali. The livelihood resilience of Bawali has been found to be 47.8% which indicates relatively low resilience to change in Sundarban mangrove due to climate change induced salinity intrusion. Contribution of natural, financial, physical, human and social capital has been fonnd to be 33.6%, 52.2%, 55.0%, 55.8%, and 48.4%, respectively, while the weights of the capitals are 25, 23, 12, 19 and 19, respectively. So it is seen that contribution of natural capital to resilience is lowest although the weight is highest, which gives indication to prioritize natural capital in formulating adaptation strategy for adaptive governance of the Sundarban socioecological system. This study gives a directive of asset based adaptation strategy to climate change induced salinity intrusion based on resilience analysis.

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ABBREVIATION

BWDB	Bangladesh Water Development Board
BLC	Boat License Certificate
DFID	Department of Foreign and International Development, UK
DOE	Department of Environment
DOF	Department of Fisheries
DROP	Disaster Resilience of Place Model
FC	Financial Capital
FD	Forest Department
GO	Government Organization
HC	Human Capital
IPCC	Intergovernmental Panel on Climate Change
MFI	Micro Finance Inctitute
NC	Natural Capital
NGO	Non Governmental Organization
PC	Physical Capital
SBCP	Sundarban Biodiversity Conservation Project
SC	Social Capital
SIZ	Sundarban Impact zone
SL	Sustainable Livelihood
SLA	Sustainable Livelihood Assessment
SLD	Shared Learning Dialogue
SLR	Sea Level Rise
SRF	Sundarban Reserve Forest
UNDP	United Nation Development Programme
UNESCO	United Nations Education Scientific and Cultural Organization

CHAPTER ONE

INTRODUCTION

1.1 Background

The evidence of human induced climate change is unequivocal (IPCC, 2007a). The climate change effects will ultimately reach the livelihood through alteration of natural resource system, ecosystem and human habitation (IPCC, 2007b). Bangladesh has been ranked second among the 27 most vulnerable countries due to its dense population in the coastal zone and low economic condition (IPCC, 2007b). The world's largest mangrove, Sundarban, is highly vulnerable to climate change effects.

Sundarban is a contiguous single-tract mangrove forest shared between two neighbonring countries Bangladesh and India (Figure 1.1). Bangladesh covers 5,773 sq km of which 4,074 sq km is mangrove and 1,699 sq km is open water bodies. Sundarban is also recognized as a site of national and international importance for conserving biodiversity due to its richness. Three wildlife sanctuaries in the Sundarban, covering an area of 139,700 ha, have been declared as world heritage site (798th) by the UNESCO in 1997. And the entire Sundarban has been declared as 560th Ramsar Site in 1992. Sundarban provides habitat for large number of plant and wild life species including several rare and endangered species of the world. It provides homes for largest population of highly endangered Royal Bengal tigers. The unique biota of Sundarban comprises 334 plant species, 49 species of mammal, 8 species of amphibian as many as 120 fish species, 315 bird species and 53 species of reptiles (SBCP, 2001).

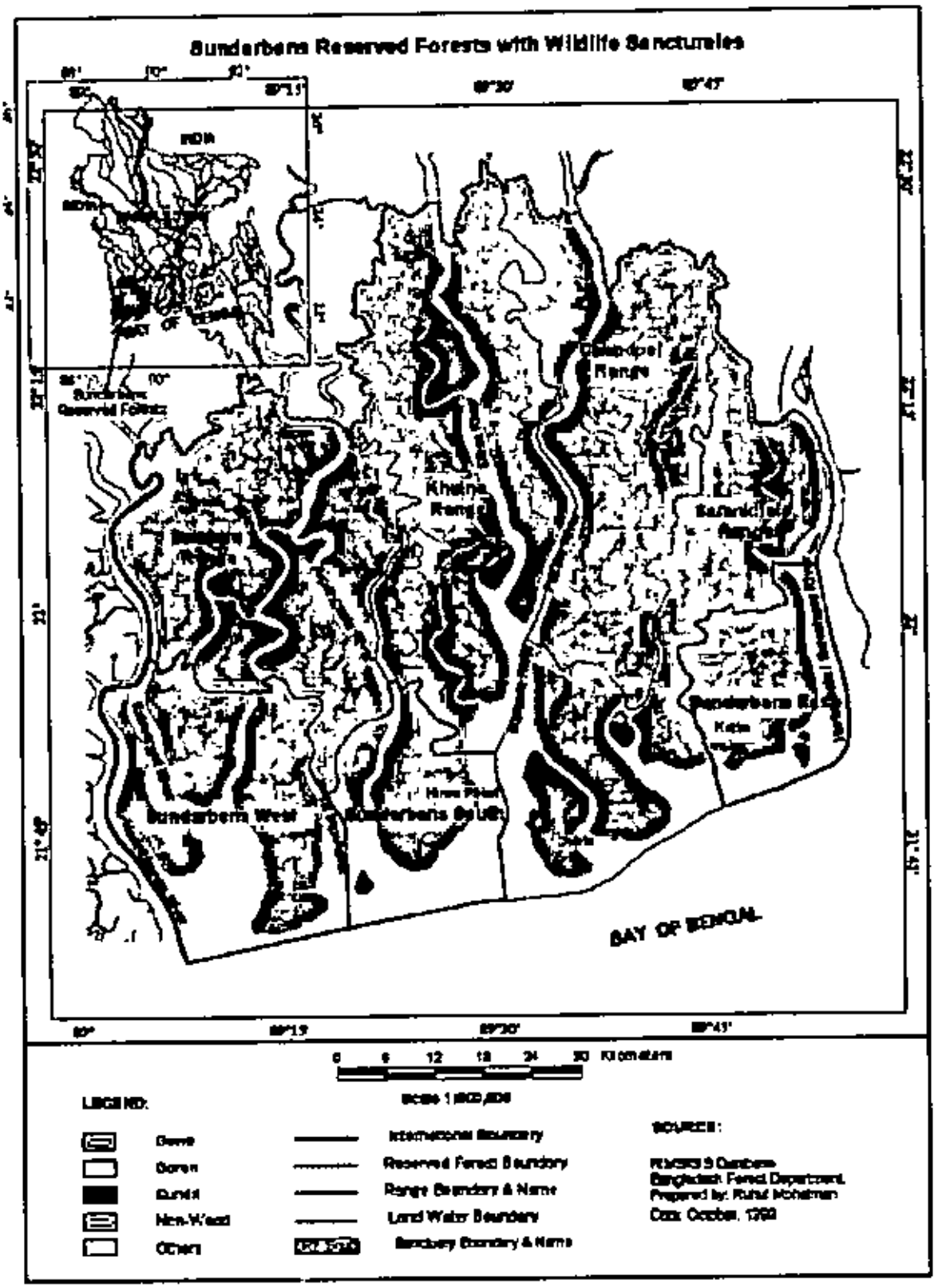

Figure 1.1: Map of the Sundarban mangrove forest (collected from forest department, Khulna)

Sundarban is a biogenous coast that exhibits significant vegetation–environmental relation, wave parameters, micro and macro tidal cycle, and long shore currents have effects on mangrove development over the geologic period (Ellison et al., 2000; BUP-CEARS-CRU, 1993). The human intervention and the dense settlement beyond the forest boundary have made the Sundarban low resilient to climate change by limiting the landward migration of mangals with relative sea rise (BUP-CEARS-CRU, 1993). Climate change is expected to affect the boundaries and areas, species composition and zonation, primary productivity, species populations and migration, the occurrence of pests and diseases, and forest regeneration by altering salinity distribution, sedimentation zone, organic accumulation, and coastal profile (Aksornkaoe and Paphavasit, 1993; CEGIS., 2006; McLeod and Salm, 2006).

The Sundarban Reserve Forest (SRF) provides a buffer for the lives, livelihoods and assets of 3.5 million people who live in its immediate vicinity (SBCP, 2001) where 1.5 million people are dependent on Sundarban for their livelihoods (Hossen et al., 2008). They are socio-economically vulnerable groups due to their low income and unstable livelihood opportunity. Climate-induced changes to forest resources will affect the viability of livelihoods. From different national and international assessment, it is clear that the forest production (both primary and secondary) is likely to change due to climate change (BUP-CEARS-CRU, 1993; CEGIS, 2006 and IWM, 2007) that makes the livelihoods of the 1.5 million people vulnerable. Vulnerability depends on their resilience to climatic stress. Livelihood resilience and adaptation strategy to climate change are important for development processes. Lack of integration of livelihood resilience and strategy limits the sustainability of development pathways. This will create low resilient and maladaptive societies that are more vulnerable to climate change. What would be the strategy to mitigate the climate change risk and to reduce the vulnerability is the key issue in climate change debate. Resilience analysis provides a ground to identify policy intervention, and mitigation measures for adaptation strategy.

1.2 Objectives of the Study

The overall aim of the study is to assess resilience of the Sundarban dependent livelihoods to salinity intrusion as a result of climate change from the perspective of the livelihood groups that will give directives of adaptation strategy. To reach this aim, the specific objectives of the study are:

1. To identify the livelihoods dependent on Sundarban Mangrove Forest;
2. To analyze the impact of climate change induced salinity intrusion on livelihood;
3. To develop an indicator framework for assessing livelihood resilience;
4. To assess livelihood resilience;
5. To suggest appropriate adaptation option.

1.3 Possible outcome of the Study

In the human development report 2007-08 of UNDP (UNDP, 2007), the emphasis has been given on the integration of livelihood resilience and adaptation strategy into the development processes and national policies to reduce the community vulnerability to climate change. The concept resilience has been widely accepted to reduce the communities' vulnerabilities to natural hazard and to changing climate, but the concept is still incomplete to make operational in the field and in the policy or risk mitigation strategies. This study will provide a conceptual ground of livelihood resilience of the Sundarban dependent community and will help to identify what measures could be taken to increase communities' resilience to climatic stress from the local people's point of views. So it is expected that the study will help the policy makers to develop an adaptation strategy in resilience thinking way.

1.4 Scope of the Study

Resilient livelihood can be defined as sustainable livelihood, which has the ability to withstand, to recover, to retard the vulnerabilities and to prepare for future through continual learning from present events. For this study only salinity intrusion was considered among the different vulnerabilities resultant from upcoming climate change. Based on the sustainability concept of livelihood, the possible impact of salinity intrusion on livelihood dependent on Sundarban was analyzed. The overall study was

conducted through participatory approach. Because the maintenance, enhancement and capacitating strategy, and performance of resource base can only be properly understood when seen from the perspective of the specific livelihood group. Therefore participatory method of investigation provided opportunity for proper understanding of livelihood resilience. During analyzing impact and developing indicator framework, Shared learning dialogues (SDL) were conducted with three livelihood group; Bawali, Mawali and fisher. But later resilience has been assessed only for Bawali. Bawali is the dominant livelihood group. Bawali depends on the primary productivity of the Sundarban which is expected to be reduced largely due to salinity intrusion, which makes the Bawali highly vulnerable to salinity intrusion.

1.5 Limitation of the Study

- The effort was to synthesize and analyze the impact of the salinity rise in the Sundarban. The data on forest production used to understand the trend of forest productivity were collected from Divisional Forest Office, Khulna. These data only accounts the forest resources that were harvested in legal ways. The amount of unauthorized extracted resource has not been accounted. SLDs reveal only the qualitative form of the productivity change.

- Weighing of the indicators was done through expert judgment and community perception. Communities were let to weigh the indicators in conventional way. No AHP or pair wise comparison were followed due to time limitation and because of large indicator framework.

- Second field visit was conducted after 10 days of cyclonic event Aila. Most of the area was inundated and people were living in cyclone shelters, road sides, and school buildings. For these reason only one learning meeting was conducted during second field visit while the plan was to conduct two learning meeting for assessing livelihood resilience. And also, participants were only 6 during that learning meeting, where it should be 8-12.

CHAPTER TWO

LITERATURE REVIEW

2.1 Climate Change and Sundarban

Mangrove forests, in their natural condition, are resilient to fluctuations in mean sea level. Mangroves have coped with sea level changes during the past 10,000 years which suggests that they can survive rates of sea level rise or fall of up to 10 to 15 mm/year (Woodroffe, 1990). In general, future rate of sea level rise, which is predicted to be a 4 mm/year (IPCC, 2007a), can be thought unlikely to endanger mangrove forest ecosystems. However, the considerable natural resilience of mangrove forests to sea level rise is seriously compromised in Bangladesh by two factors (BUP-CEARS-CRU, 1993). First one is the possible future landward migration of the Sundarban, as sea level rises, which is not possible due to dense human settlement just beyond the forest border. And the second is the forest health, which is on detritus state (CEGIS, 2006). The result is that the Sundarban mangrove is vulnerable and low resilient to climate change.

However the mangrove ecosystem is still imperfectly known and understood. Moreover, it is an open ecosystem interacting other coastal ecosystem that makes the vulnerability study more complex. The vulnerability of Sundarban arises from the possible changes in sea level rise, salinity, sedimentation, wind pattern, ocean current and mean temperature. Coastal profile is changing and impact of climate change is being observed. The annual maximum tidal range has increased by 0.75m in the eastern and central parts of the Sundarban by the last two decades (Wahid et al., 2007). Inundation depth and area is increasing and water salinity is rising (Islam and Gnauck, 2008; Wahid et al., 2007; Hoque et al, 2006; CEGIS, 2006).

Climate change is expected to affect the boundaries and areas, species composition and zonation, primary productivity, species populations and migration, the occurrence of pests and diseases, and forest regeneration. This is due to salinity intrusion, sedimentation, organic accumulation, and changes in coastal profile (Aksornkaoe and Paphavasit, 1993; CEGIS., 2006; McLeod, et al., 2006; Wahid et al., 2007). Sunduri is the key species in the Sundarban and the Sunduri typed forest represents healthy and

diversified zone in the Sundarban. The suitable area of Sundri will be reduced to 10% and 50% with 32cm and 88cm SLR respectively (CEGIS, 2006).

2.1.1 State of salinity rise in Sundarban

In general, salinity increases in the rivers of Sundarban from east to west direction during monsoon (minimum salinity in August–September) and during peak salinity (April–May) while it increases from north east to south west during the other periods (Wahid et al., 2007; CEGIS, 2006) (Figure 2.1). Seasonal variation of salinity shows that 60% area remain in high salinity (>20ppt) for at least 1.5 months of the year (Wahid et al., 2007).

All of rivers in the Sundarban have increasing trend of water salinity and crossing threshold line (20 ppt) (Islam and Gnauck, 2008; Hoque et al., 2006). The high saline affected area extends from south to north and east to west direction (Islam and Gnauck, 2008). Because of the increasing trend in salinity, the isohaline map of the Sundarban is gradually changing (Islam and Gnauck, 2008; Hoque et al., 2006) (see Figure 2.2 and 2.3).

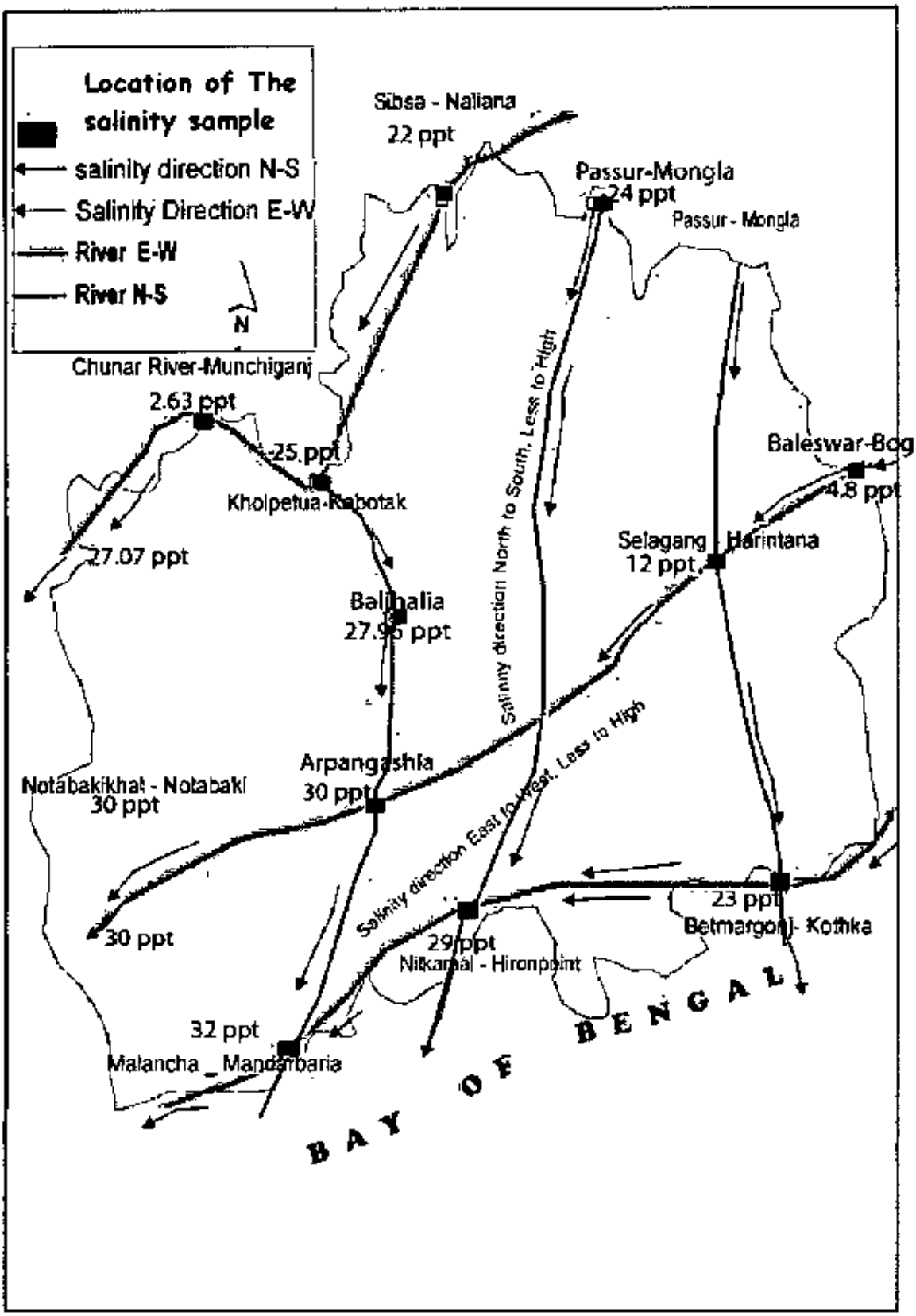

Figure 2.1: Salinity distributions in Sundarban (adopted from Islam and Gnauck, 2008)

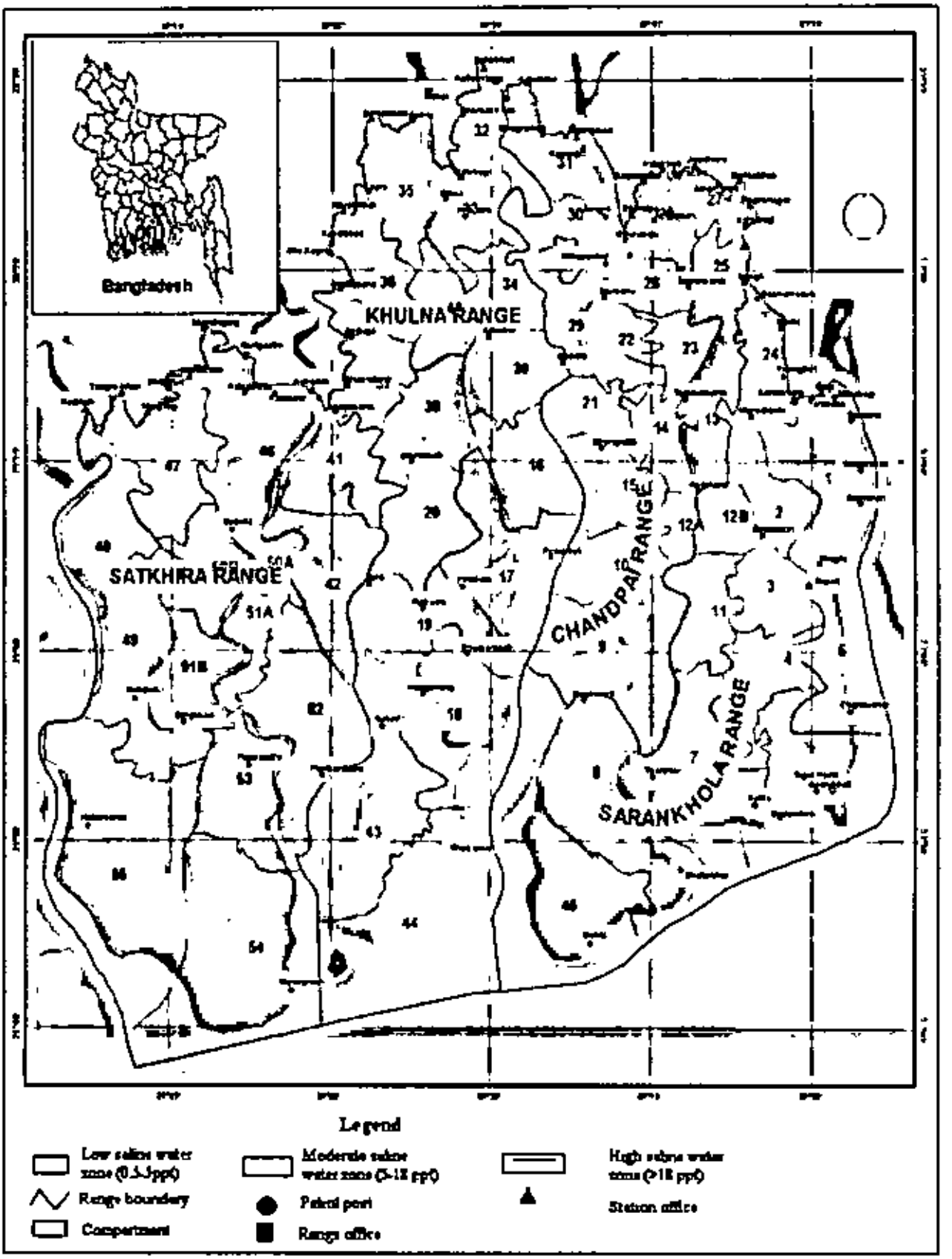

Figure 2.2: Map of three saline water zones in Sundarban during 1983 (from Hoque et al., 2006)

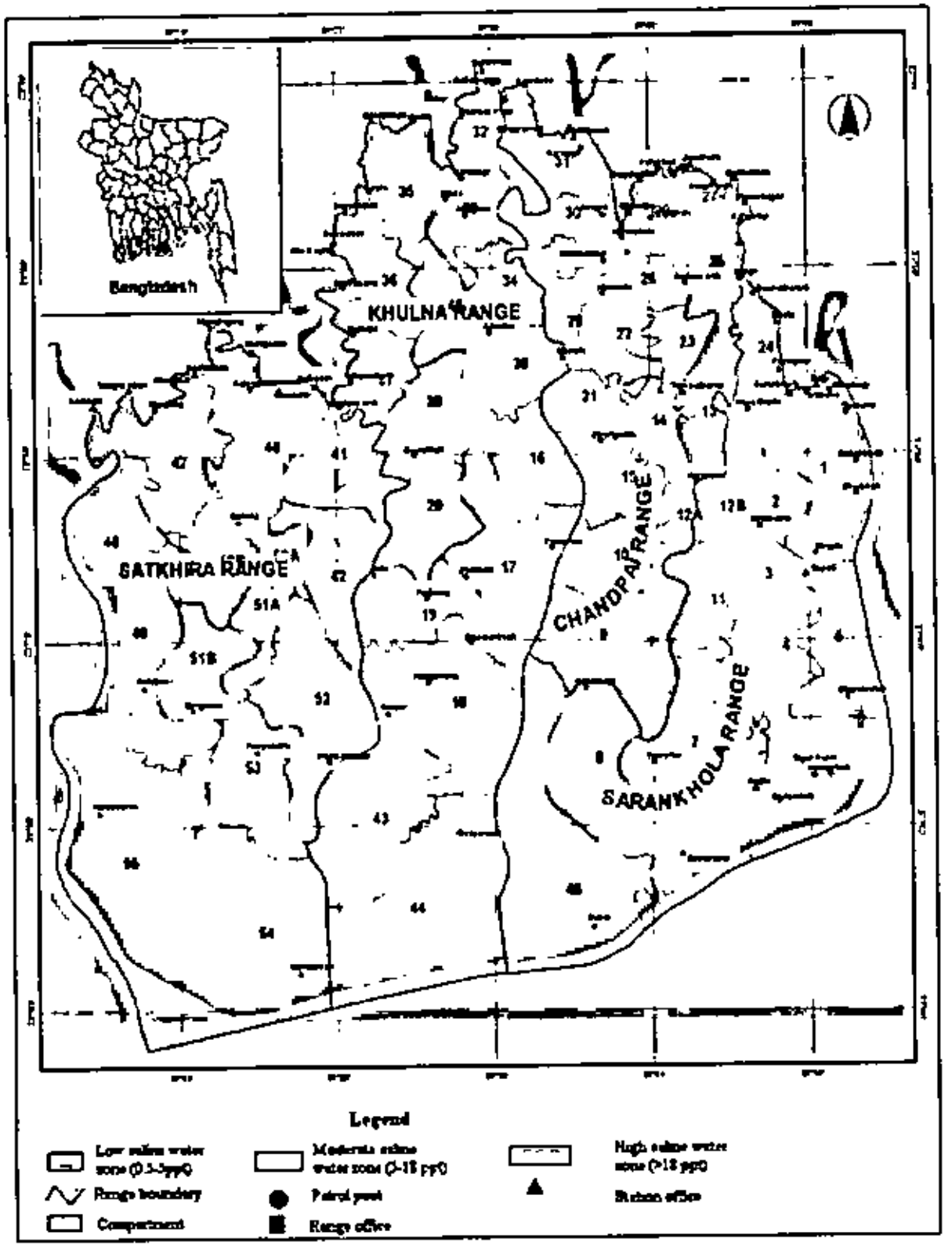

Figure 2.3: Map of three saline water zones in Sundarban during 2001-2003 (adopted from Hoque et al., 2006)

Climate change induced sea level rise will push the salinity front toward inland. Under base condition, low saline water zone (5ppt-10ppt), moderate saline water zone (10ppt-20ppt) and high saline water zone (>20ppt) are; 45%, 50% and 5 % respectively (Figure 2.4). Due to 88cm SLR, these areas of low saline water and moderate saline water zone will be reduced to 36% and 47% respectively (Rahman 2008). From the study of Rahman (2008), it could be estimated that, 20% of low saline zone of Sundarban will be transformed into moderate saline water zone and 25% of moderate saline water zone will be transformed in to high saline zone from the base condition due to 88cm SLR (Figure 2.5).

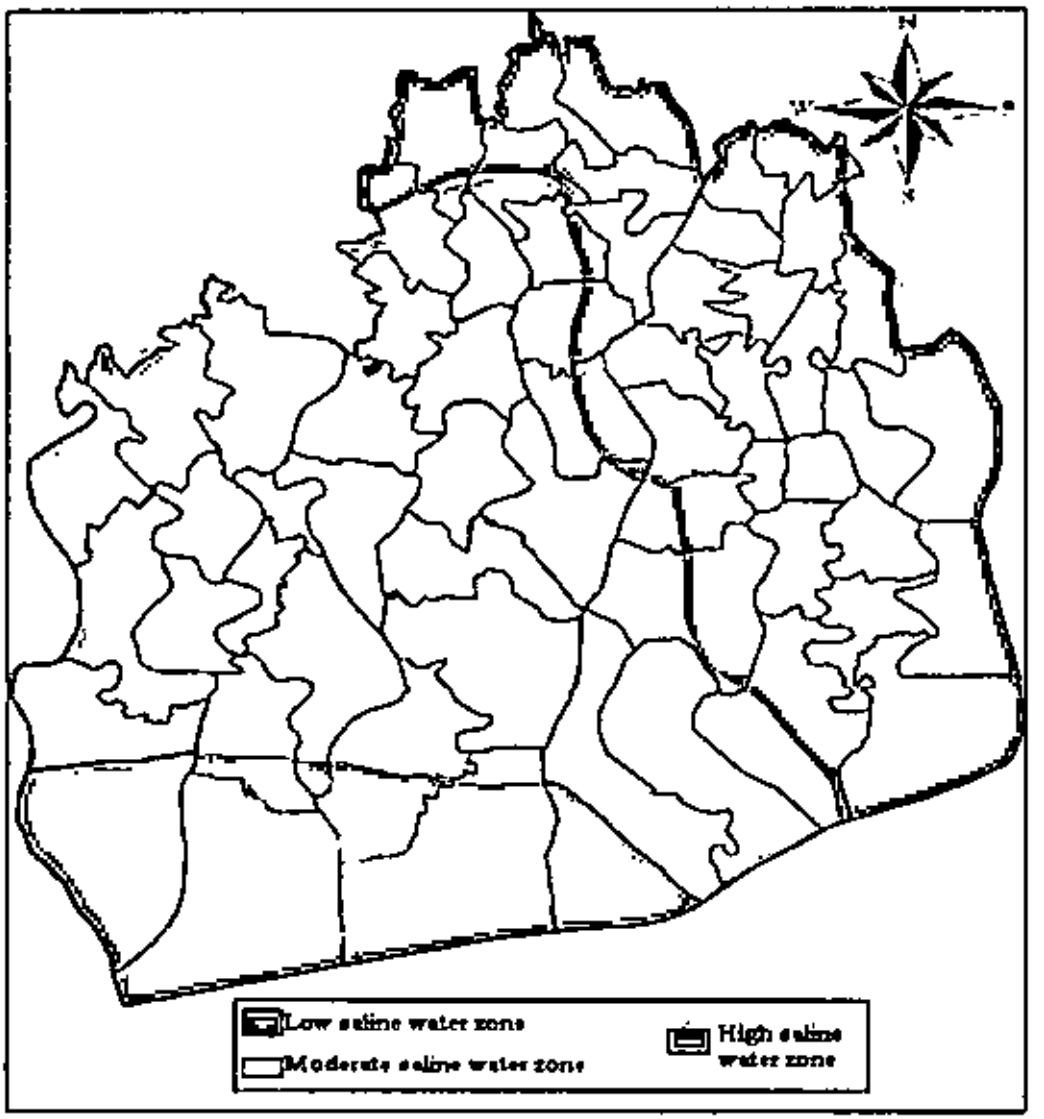

Figure 2.4: Salinity distribution map of Sundarban at base condition

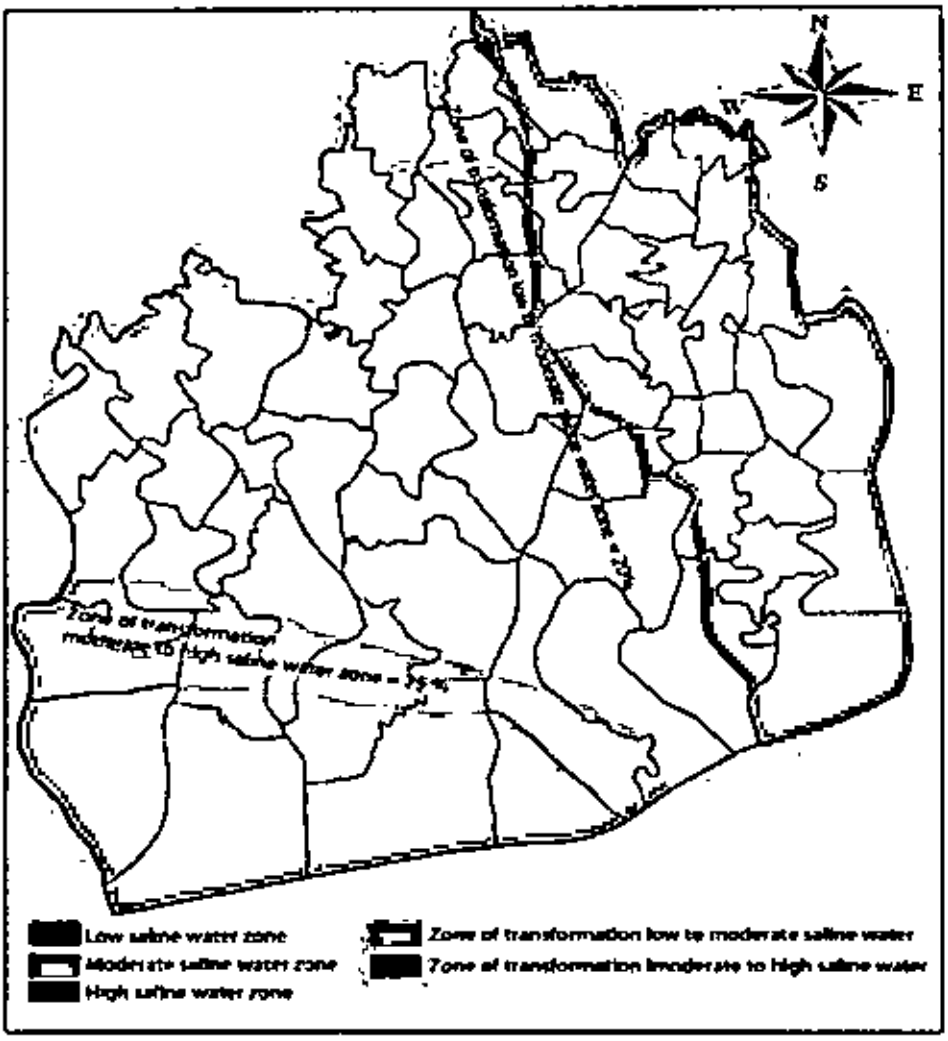

Figure 2.5: Salinity distribution map of Sundarban at 88cm SLR condition

2.1.2 Fate of Sundarban mangrove forest due to climate change induced salinity intrusion

Generally the plant distribution within the Sundarban is followed by the salinity, ground elevation and depth of inundation (Hossain, 2008; Elisson et al., 200; Rahman, 1998; McLeod and Salm, 2006). As the salinity of Sundarban increases from east to west, density of vegetation growth and canopy course decreases from east to west. The height of the different species in Sundarban is also related with salinity (CEGIS, 2006; Chaffey et al., 1985).

Ecological successions of vegetation also differ with the variation of salinity. A significant decrease in regeneration and growth is noticed with an increase in salinity (Siddique, 2001). The germination of seedlings, metabolic activities are dependent on salinity. Salinity reduces the productivity, growth of the mangrove timbers (McLeod

and Salm, 2006). Salinity increases the water density as a result the osmotic gradient is increased. Then without tidal flashing the old plant cannot pump their sap against increased osmotic gradient that cause the mortality of old trees. The top dying disease, root rot disease is due to increase of salinity and fungal infection (Hoque et al., 2006; CEGIS, 2006; Rahman, 1998). The survival capacity of seedlings is decreased with increase of salinity (Siddique, 2001). Natural regeneration of vegetation and forest succession depends on salinity regimes (Karim, 1994 and Siddique, 2001). High dense human settlement outside the forest restricts the migration of species to less saline area. Climate change induced SLR would therefore threaten the very existence of the ecosystem.

It has been observed that due to gradual increase of salinity, freshwater loving sundry trees are disappearing and that area has been covered by shrubs and salinity tolerant other species like Gewa, Keora, grass or others (CEGIS, 2006, Hossain, 2008). The Sundri has decreasing trend in generation density from lower to high saline zone (CEGIS, 2006; Hossain, 2008).

From the above discussion, it is clear that Sundarban mangrove forest is highly vulnerable to climate change induced salinity intrusion. The quantification of the vulnerability and speculation of the change in forest ecosystem is difficult and has rarely been done. Future change in Sundarban ecosystem due to SLR induced salinity intrusion has been analyzed in the study of Rahman (2008). The study speculates 13% loss in productivity and 27% loss in regeneration due to salinity intrusion from 88cm SLR. In Table 2.1 details of the speculated changes in forest productivity and regeneration according to Rahman (2008) are shown.

Table 2.1: Speculated changes in forest productivity and regeneration due to SLR induced salinity intrusion.

Vulnerabilities to 88cm SLR	Zone of transfer	Speculation
Loss in Productivity	Low saline to moderate saline	7%
	moderate saline to high saline	6%
	Total	**13%**
Loss in Regeneration	Low saline to moderate saline	22%
	moderate saline to high saline	5%
	Total	**27%**

(Adopted from Rahman, 2008)

2.2 Livelihood Dependent on Sundarban

In the impact zone of Sundarban 18% of the households are dependent on Sundarban for their live and livelihoods (PDO-ICZMP, 2004). While 1.4 million people are indirectly and 0.25 million people are directly dependent on Sundarban for their livelihoods (Hossen et al., 2008). Their livelihood is resource extraction from Sundarban. Table 2.2 gives details of the population dependent on Sundarban mangrove forest according to their livelihood activities. Bawalis collect wood and Nypa palm from Sundarban; Chunery collect oyster and snail from the adjacent rivers and wetland of Sundarbans. Fisher showed in the table 2.2 also involved the fisher of the Bay of Bangle and rivers near the Sundarban.

Table 2.2: Population dependent on Sundarban

Livelihood group	Population dependent on Sundarban	
	Directly	Indirectly
Bawali (wood cutter)	80,000	4, 00,000
Mawali (honey collector)	15,000	50,000
Fisher*	1, 40,000*	5, 00,000*
Chunary (oyster and snail collector)	4,000	30,000
Firewood collector	8,000	30,000
Carpenter	10,000	40,000
Total	2, 57,000	10, 40,000

Source: Hossen et al., 2008

Notes: * including fishers of the rivers and sea near the Sundarban

2.3 Livelihood Resilience

The term resilience is not a new one. Emerging form the ecology, the term resilience was developed as a concept of capacity of absorbing shock in case of physical system. Now it has become multidisciplinary issue in the discipline of disaster management supplanting the engineering based thinking of disaster risk reduction. In recent era, this concept has been reemerging through the lens of climate change, and now this is in the center position of all climate change oriented research.

Resilience provides the capacity to absorb shocks while maintaining function and shifts policies from those that aspire to control change in systems assumed to be stable, to managing the capacity of social-ecological systems to cope with, adapt to, and shape change (Folke et al., 2002). Resilience is not only the ability of recovering the shocks and bouncing back to the previous condition, as it is defined by the several researchers (e.g., Brown, 1996; Paton and Johnston, 2001; Klein et al., 2003; Coles and Buckle, 2004; Butler, 2007), because bouncing back is not always desirable and it will again make the system vulnerable to future disaster (Klein et al., 2003). Moreover, resilience buffers adversity (Ahmed, 2004), absorbs and withstand the shocks (Holling, 1973; Adger, 2000; Longstaff, 2005) takes continual learning (Folke, 2006; Berkes, 2007; Gardner and Dekens, 2007; Cutter et al., 2008) and gives preparedness for future shocks (Bruneau et al., 2003; Pfefferbaum, 2005; Gardner and Dekens, 2007; Cutter et al., 2008). These attributes of resilience could be best understood from Panarchy model (Gunderson and Holling, 2001) where resilient system has been defined as, creating and conserving system consists of series of interactive adaptive cycle. Panarchy model suggests that interaction with and within adaptive cycles provides continual learning from previous experience. Recovery from the hazard impact depends on social learning from past hazards, and this learning gives future preparedness through mitigation and adaptation. Thus adaptation, adaptability, mitigation and preparedness become the integral parts of the resilience (O'Brien et al., 2004; Gardner and Dekens, 2007; Cutter et al., 2008).

Resilience is shaped by the macro-economic situation (at national level) and micro economic well being (e.g., crop insurance, savings at local level) (O'Brien et al., 2004). Economic situation gives indication of resilience but resilience is not only the outcome of economic attributes of the community or nation. Resilience of a socio-ecological system depends on properties of natural and social system that structure dynamics of the natural and social system (Moench et al., 2004; Plummer and Armitage, 2007). Local resource base (ecosystem, socio-ecological system and socio-physical system) on which community is dependent is the nesting ground of the resilience (Adger, 2000; Paton et al., 2001). Resilience also relies on the capacities of the communities to generate and operate these resources and human-environment interaction through adaptive comanagement, particularly in case of the community dependent on single

large ecosystem like forest (Paton et al., 2001). This human-environment interaction through adaptive comanagement sustains the livelihood groups dependent on forest ecosystem.

Consisted with the aforementioned concept it could be summarized that livelihood resilience is the ability of a livelihood group to buffer the vulnerabilities, to withstand the shocks, to recover the impacts, and to prepare for future vulnerabilities by taking continual learning from vulnerabilities. This resilience depends on the capacity of livelihood group to manage and operate their livelihood capitals, capacity of livelihood capitals to function on above mentioned resilient processes of livelihood group (buffer adversity, withstand the shock, recover the impact) and sustainability of livelihood capitals.

2.4 Theoretical Approaches of Assessing Livelihood Resilience

There are numeric approaches and models have been developed for understanding and assessing the resilience of the community through the use of composite indicators (e.g Norris et al., 2008; Cutter, 2008; Rose, 2007; Mayunga, 2007; Brenkert and Malone, 2005; etc). Assessment of resilience is dependent on scale (O'Brien et al., 2004). Through national level assessment, a country may be seemed as resilient but local level assessment may reveal some disparities. Scale of assessment is important during assessing the resilience. Regional and local level assessment provides strong basis for understanding vulnerability and resilience. The assessment of resilience at the local level (i.e. community, livelihood and household) confronts several challenges while most of the studies direct the way of national level assessments.

Paton et al. (2001) identified three predictor of community resilience; self efficiency, problem-focused coping and age. Sapountzaki (2007) identified four key determinants of resilience; i) the agency performing the process, ii) the stimulus, iii) the resources utilized, iv) the spatial and temporal range of the process and v) the final out come. Both of these studies are conceptually grounded, that direct and provide general basis of community resilience. But it requires a complete set of indicators to make the theory operational.

Tobbin's model (Tobbin, 1999) of sustainable and resilient communities combines three theoretical models, mitigation model, recovery model and structural-cognitive model. Political and constituency support, risk reduction, long term rehabilitation, resource re-accumulation and distribution, government support and aid, are the means of community resilience. And the resilience could be assessed by accounting social change, physical location, income, health, education, gender, social networks, and other psychological and attitudinal factors. But this model is not applicable to all scale. The model best fits at national level assessment but not at local level. Again this model doesn't address the natural resources or factors which are important in case of socio-ecological system or community dependent on natural resources (like forest).

Bruneau et al.'s framework of community resilience (Bruneau et al., 2003) provides directives and measures of resilience assessment where they theorized the dynamic attributes of the resilience i.e., robustness, redundancy, resourcefulness and rapidity. The resilience model is grounded on performance of the community services (health system, emergency management system, electricity system, water supply system and other social utilities). The model is more appropriate in municipal community rather than rural community where these social utilities are absent. However the model provides the conceptual ground of resilience and determinants of community resilience.

Norris et al.'s framework of resilience (Norris et al., 2008) based on the both dynamic attributes of the Bruneau et al.'s resilience model (bruneau et al., 2003) and static properties of the community resources. This framework describes the resilience as a networked capacity of community resources. But the framework only addresses the economic and social resources where natural resources play a dominant role in community particularly the forest dependent community.

One of the explicit and well understandable conceptual resilience models is 'Disaster Resilience of Place' (DROP) model (Cutter et al., 2008). DROP model presents resilience as a dynamic process dependent on static condition and hazard characteristics i.e., time, frequency and magnitude. This model is conceptually grounded to assess community resilience to natural disaster where resilience depends on natural system, social system, and built environment. It also gives a general indicator framework that would be applicable to address any disaster and at any scale (micro-meso). As it is

general, it requires modification before applying in different communities or group particularly in case of livelihood groups who are directly dependant on natural resources and to whom local resource base is more significant than individual assets.

Household asset based approach is a familiar method for assessing resilience and vulnerability at local level that is practiced by the individual researchers and developing agency also (eg., Heltberg et al., 2009; Hanh et al., 2009; Keil et al., 2008; Mayunga, 2007; Elasha et al., 2005; Pelling and High, 2005; etc). In asset based sustainable livelihood approach, livelihood system is delineated into five livelihood capitals having different function (i.e., natural, financial, physical, human and social). Livelihood resilience depends on the interface between risk; assets; and the policy, institutional, and structural context (Heltberg et al., 2009). Resilience depends on the function of the livelihood capitals (Keil et al., 2008), functional diversity of the system (Adger, 2000), and sustainability concept is the central part of the resilience study (Cutter et al., 2008; Tobbin, 1999). Asset based sustainable livelihood approach is useful for assessing the ability of household to withstand the shocks by addressing the sensitivity and adaptive capacity (Hahn et al., 2009). The asset base reflects the risk and initiatives taken to mitigate risk, which determine the resilience (Keil et al., 2008). Aforementioned concepts of resilience and attributes of sustainable livelihood approach explicitly indicate that sustainable livelihood approach brings out the best understanding of livelihood resilience.

2.5 Expected Application of Livelihood Resilience

The concept of resilience would be applicable in resource management and maintenance of predictable world (Holling, 1973). Maintenance of predictable world is the burning issue in changing climate era. What would be our future scenarios in changing climate and what would be our social development process that is resilient to changing climate is key thing in climate change debate.

Resilience shapes the strategy for disaster readiness and recovery (Norris et al., 2008) and more elusive hazard planning (Tobin, 1999). Resilience analysis brings out the variables and processes (social, physical and ecological) that structure the socioecological system and which are the sources of adaptive governance (Folke,

2006). Resilience analysis shows the pathway to potential sustainable socio-ecological system (Olsson et al., 2004). Resilience analysis also brings out the elements that are needed to modify and to boost up (Bruneau et al., 2003). Development process based on resilient management has attributes of adaptability, continual learning and actively adapting management policy that response to change in socio-ecological system (Holling, 1973; Olsson et al., 2004). Resilience framework will help the policy makers to identify appropriate measures to mitigate risk, to take appropriate policy intervention and to prepare an adaptation strategy which has itself resiliency to adapt to future change in socio-ecological system.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Selection of the Study Area

The study area was selected within the impact zone of the Sundarban. The impact zone of the Sundarban was defined during the Sundarban Biodiversity Conservation Project (SBCP) based on the direct economic influence of the Sundarban. The area is defined as the 20-km strip of land adjacent to Sundarban considering that bulk resource harvesters live in this area (Iftekhar and Islam, 2004). Sundarban impact zone (SIZ) consists of Sundarban reserve forest and 17 thana immediately adjacent to Sundarban and also most dependent on Sundarban for livelihood activities. Within the SIZ two villages (Beledanga and 4 no Koyra) of two unions (Amadi and Koyra) under Koyra Upazila which is most adjacent to Sundarban were selected for conducting Shared learning dialogue (SLD). The selection criteria were accessibility to Sundarban, availability of the target livelihood group and the likely impact of climate change induced salinity intrusion. Koyra upazila is surrounded by the Khulna range on the right and Sathkhira range of the Sundarban on the left (Figure 3.1). Concentration of Sundarban dependent livelihood groups is highest in Koyra among the 17 thana within the SIZ. Livelihood groups dependent on Sundarban living in this upazila frequently go fresh water zone to high saline water zone of the Sundarban (zonation according to surface water salinity) for their livelihood activities which gives indication of having good knowledge and experience about the health and productivity status of the whole Sundarban which was important for conducting this study.

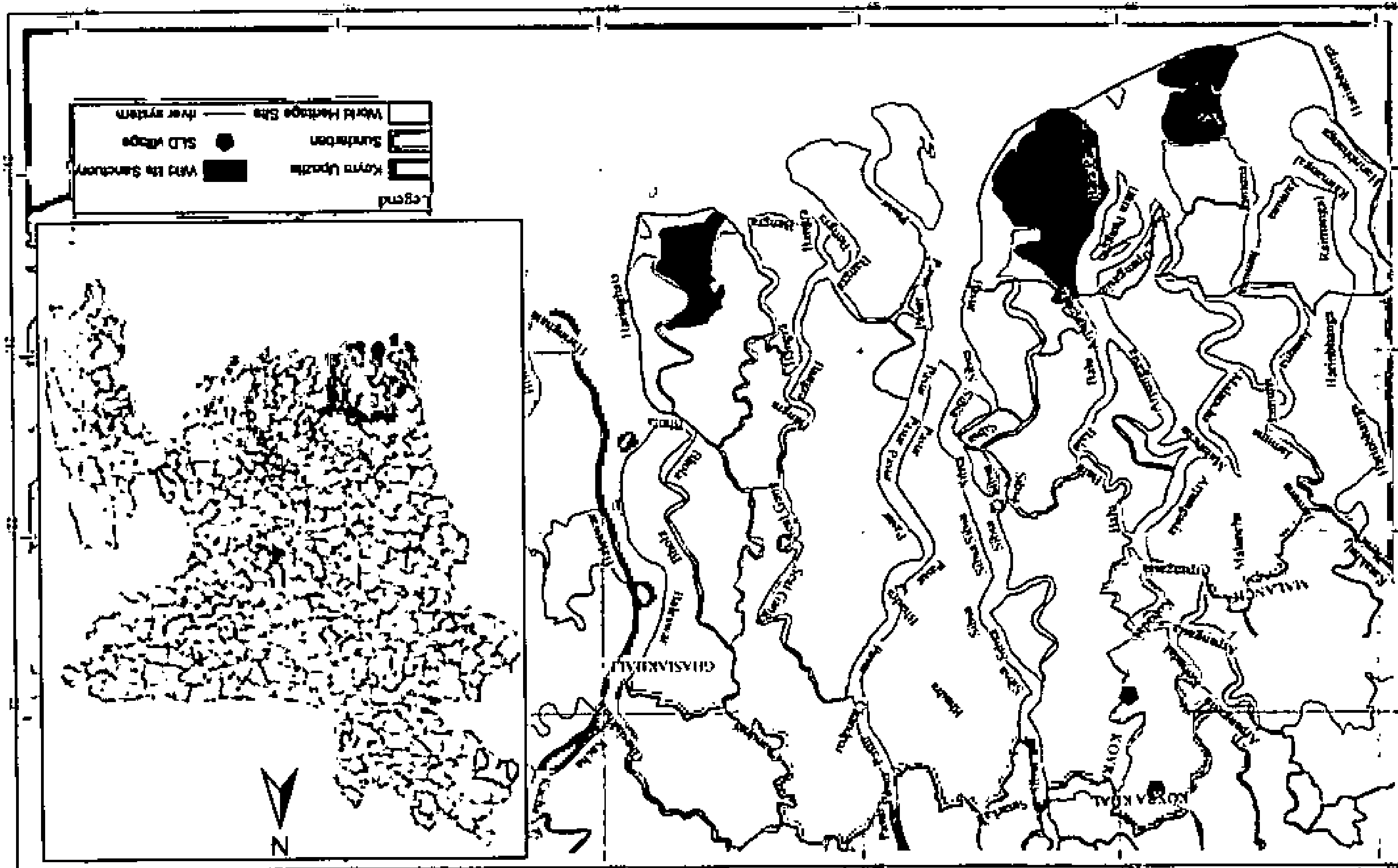

Figure 3.1: Location of the Study area

3.2 Research Design and Data Collection Techniques

The research was designed to conduct through participatory approach. The study is based on qualitative and quantitative data. Both primary and secondary data were collected for this study. Secondary data were collected from forest department, IWM, CEGIS and through reviewing of different national and international literatures. And primary data were collected from the community by using participatory tools: resource mapping and seasonal calendar followed by participatory method. The primary methods of the study are; SLD that ensures complete participation of the target community (livelihoods dependent on Sundarban) and Sustainable livelihood assessment (SLA). Primarily, every parts of the study (livelihood identification, impact analyzing and indicators identification) were made through literature review which have been refined and verified through SLD later.

3.2.1 Shared learning dialogue

SLD was the primary methodological process followed throughout the study to refine and verify preliminary assumptions, and simultaneously it ensured the participatory process in the study. SLD provided the ground of iterative transfer of information, knowledge and experience between researcher and local community.

SLD is an iterative process consists of series of learning meeting in which analyst and different communities of actors can share insights and come to a common understanding (Moench et al., 2008). SLD is grounded on two way communication and reflexive learning process to build common understanding. This method is very useful to draw community participation in the process of research about the issue having multidimensional context. Climate change related research is the appropriate field to apply the SLD method where multidimensional issues from multidimensional sources are involved.

In SLD process, clarification of the research purposes, research issues, problems are done in more explicit way to make the community well understood about the research issues and problem. The clear understanding of the problem reflects effective participation in research process and data collection.

3.2.2 Organizing and administering SLD

SLD process was followed at the three parts of the study: i) analyzing impact of salinity intrusion, ii) developing indicator framework and iii) assessing livelihood resilience followed by the framework. The main learning goals of the SLD were i) to refine and verify the preliminary assumptions about livelihood groups, impacts of climate change induced salinity intrusion and the indicator framework for assessing livelihood resilience and ii) analyzing and assessing livelihood resilience. The SLD process was executed by conducting three learning meetings during two field visits at two villages of SIZ with Sundarban dependent livelihood groups (see Figure 3.1) during two field visits. It was tried to keep the number of participants within 10-12, except the third meeting because of unfavorable situation due to cyclone Aila. Participants' livelihood groups and total number has been given in Table 3.1.

Table 3.1: Participants' livelihood groups and total no of participants in SLD

SLD no	Place (village)	Union	Livelihood groups	No of participants
First field visit: Developing Indicator framework and refining assumptions				
1	Beledanga	Amadi	Bawali (wood cutter/Nypa collector)	5
			Mawali (Honey and bee wax collector)	7
Total participants				**12**
2	4 no Koyra	Koyra	Fisher	6
			Bawali (wood cutter/Nypa collector)	4
Total participants				**10**
Second field visit: Resilience assessment				
3	Beledanga	Amadi	Bawali	6

Learning meetings were informal meeting with Sundarban dependent livelihood groups. Meeting places and time were selected by the communities. Two PRA tools; resource mapping and seasonal calendar were used to collect qualitative data and to understand livelihood strategies. Figure 3.2 represents the shared learning process of this study.

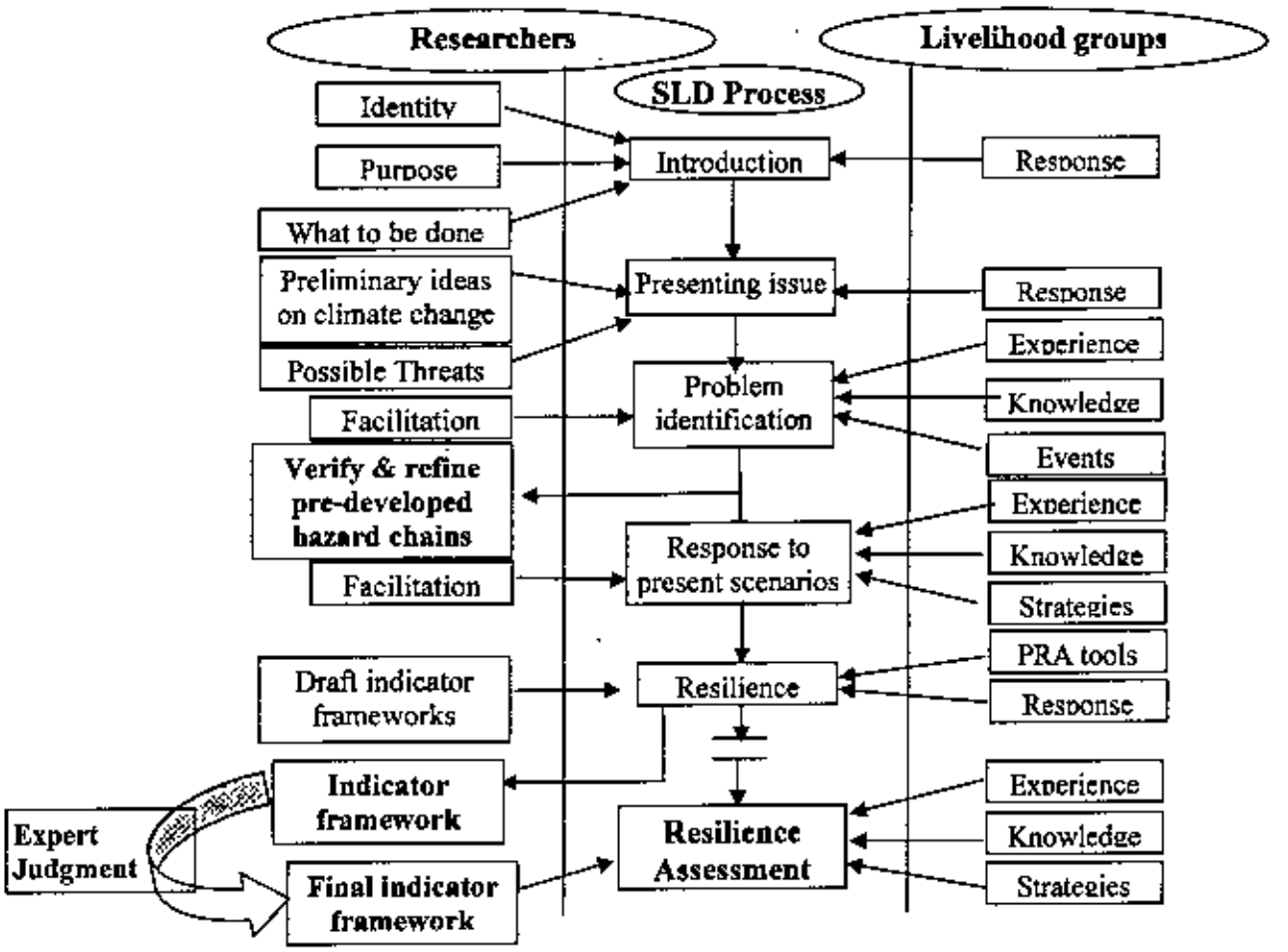

Figure 3.2: Process of SLD

3.2.3 Sustainable livelihood assessment

The overall study was followed by SLA method, where livelihood was delineated into five livelihood capitals (natural, financial, physical, human and social) according to SLA framework of DFID (Carney, 1998). The SLA is a concept of transboundary and interdisciplinary (Knutsson, 2006). The SLA method provided a framework for addressing strength, weakness and opportunities of the community. For this study the livelihood resilience has been defined through the lens of sustainable livelihood (adopted from Sadik and Rahman, 2009, Elasha et al., 2005 and Tobbin, 1999). The impact of climate change induced salinity intrusion on Sundarban dependent livelihood groups and the resilience assessment were done based on the SLA method.

3.3 Identifying livelihood groups

Primarily the livelihood groups were identified through literature review and field observation. Then the preliminary identifications were refined and verified through Shared Learning Dialogue (SLD) method.

3.4 Analyzing impact of salinity intrusion on livelihood

Climate change threats to Sundarban were identified through reviewing several national and international assessments (e.g., Wahid et al., 2007; IWM, 2007; Hoque et al., 2006; CEGIS, 2006; BUP-CEARS-CRU, 1993). Reviewing of existing literature helped synthesize the concept of climate change threats to Sundarban and to identify the specific threats of climate change to Sundarban mangrove system. The impact was analyzed through SLA approach by developing hazard development chain that gave bener understanding of the process of developing hazard after salinity intrusion.

3.5 Farming Indicator Framework for Assessing Livelihood Resilience

3.5.1 Process of selection

The goal was to develop a composite set of qualitative and quantitative indicators around each of the five livelihood capitals which will be applicable to the livelihood groups and will be the reflector of communities' perceptions. Indicators were chosen following three steps (Figure 3.3);

i) theoretical approach through literature review,

ii) understanding relationship between livelihood and mangrove through SLD and

iii) practicality through self judgment.

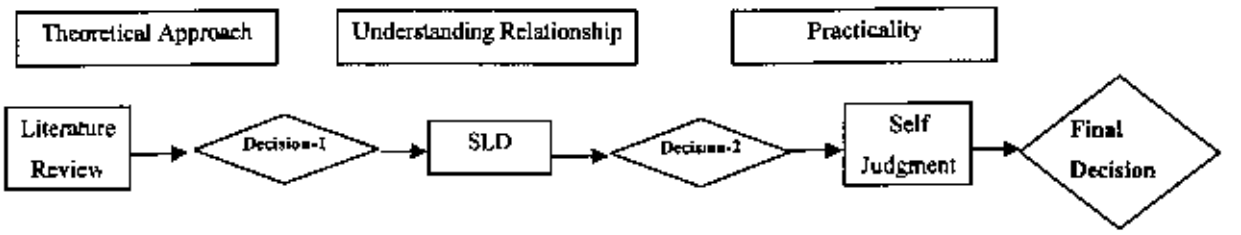

Figure 3.3: Process of indicator selection

Preliminarily a composite set of criterion with possible set of indicators were selected based on literature review. This premature framework was screened through SLD with Sundarban dependent livelihood groups by understanding the relationship of indicators with salinity intrusion, livelihood capitals and the livelihood groups. Then the first-screened framework was screened again based on data availability and easy applicability according to self judgment.

3.5.2 Structuring the indicator framework

The resilient system have four key properties i.e., robustness, redundancy, rapidity and resourcefulness (Bruneau et al., 2003). These 4Rs work as dynamic attributes of the resources rather than as properties of the resources (Norris et al., 2008). 'Robustness' is the ability to withstand the shocks without suffering degradation (Norris et al., 2008) while in social system, the ability of avoiding the causalities and disruptions determines the robustness (Bruneau et al., 2003). 'Redundancy' is the synonymous of resource (household assets) diversity (Norris et al., 2008) and alternative means of providing the community needs or livelihood opportunity is the measure of redundancy (Bruneau et al., 2003). Rapidity is the capacity to achieve goal in timely manure and 'resourcefulness' is the capacity to identify problems and mobilize resources (Norris et al., 2008). Rapidity is determined by the ability of optimizing time required to go back pre state and resourcefulness is determined by the plans and resources to meet the community needs (Bruneau et al., 2003).

Resilience rests on both the static properties and the dynamic attributes (4Rs) of resources (Norris et al., 2008) but for measurement purposes it has been often considered as static purposes (Cutter et al., 2008). In this study effort was to capture the combination of static properties and dynamic attributes. In order to capture this combination, indicators were selected from three dimensions i.e., productivity, sustainability and risk (adopted from Elasba et al., 2005). Productivity and risk

determine the static properties by analyzing strength, weakness and opportunities. Sustainability determines the dynamic attributes by analyzing continual learning from shocks, adaptability in strategies and plans, preparedness for the future. Thus productivity, sustainability and risk provide the main conceptual basis for selecting indicators of livelihood resilience.

Building on the SL approaches the indicators were selected around each of the five livelihood capitals i.e. natural, physical, financial, human and social. The indicator framework is structured on five livelihood capital and gives qualitative level of livelihood resilience of forest dependent community to climate change induced salinity intrusion.

3.6 Assessing Livelihood Resilience

Followed by the indicator framework based on the sustainable livelihood approach the livelihood resilience was defined as the function of five livelihood capitals. Quantification of the livelihood resilience was done by cumulating the contribution of five livelihood capital (equation 3.1). Resilience contribution of individual livelihood capital was quantified by the equation 3.2-3.6. These equations give resilience in the scale of 100.

$$R = \frac{(W_{tN} * R_N + W_{tF} * R_F + W_{tP} * R_P + W_{tH} * R_H + W_{tS} * R_S)}{(W_{tN} + W_{tF} + W_{tP} + W_{tH} + W_{tS})} \quad (3.1)$$

Here,

R = livelihood resilience

R_N= Resilience contribution of natural capital

R_F = Resilience contribution of financial capital

R_P = Resilience contribution of physical capital

R_H = Resilience contribution of human capital

R_S = Resilience of social capital

$W_{tN/F/P/H/S}$ = Total weight of natural/financial/physical/human/social capital

$$R_N = \frac{100}{5 * W_{iN}} \sum_{n=1}^{N_N} (W_{INn} * I_{Nn}) \quad (3.2)$$

$$R_F = \frac{100}{5 * W_{iF}} \sum_{n=1}^{N_F} (W_{IFn} * I_{Fn}) \quad (3.3)$$

$$R_P = \frac{100}{5 * W_{iP}} \sum_{n=1}^{N_P} (W_{IPn} * I_{Pn}) \quad (3.4)$$

$$R_H = \frac{100}{5 * W_{iH}} \sum_{n=1}^{N_H} (W_{IHn} * I_{Hn}) \quad (3.5)$$

$$R_S = \frac{100}{5 * W_{iS}} \sum_{n=1}^{N_S} (W_{ISn} * I_{Sn}) \quad (3.6)$$

Here,

$W_{IN/F/P/H/S\ n}$ = Weight of n-th indicator of natural/financial/physical/human/social capital

$I_{N/F/P/H/Sn}$ = Score of n-th indicator of natural/financial/physical/human/social capital

N_N = No of indicator for natural capital

N_F = No of indicator for financial capital

N_P = No of indicator for Physical capital

N_H = No of indicator for Human capital

N_S = No of indicator for Social capital

3.7 Formulating Adaptation Strategy

The resilience analysis of livelihood group brought out a plausible adaptation strategy to climate change induced salinity intrusion. The directive of adaptation strategy was formulated based on, analysis and synthesis of secondary materials, SLD and direct understanding from fields in the manner of resilience analysis.

CHAPTER FOUR
ANALYZING IMPACT OF SALINITY INTRUSION ON LIVELIHOOD DEPENDENT ON SUNDARBAN

4.1 Identifying Livelihoods Group Dependent on Sundarban

Around 1.4 millions people are dependent on Sundarban where 0.25 millions are directly dependent on it for their household income (Hossen et al., 2008). Primarily 9 livelihood groups were identified by reviewing existing literatures (e.g., Kabir and Hossain, 2008; Hossen et al., 2008; PDO-ICZMP, 2004 and SBCP, 2001) which were; Bawali (wood cutter), Nypa (golpata used as roof materials) collector, Mawali (honey and bee wax collector), Jele (Fisher), Majhi (Boatman), crab collector, medicinal plant collector, shrimp fry collector and Chunery (oyster and snail collector). After field observation and SLD it has been found that in practical, these resource extractors have diversified their livelihood opportunity by extracting different types of resources in responding to decreasing productivity status of Sundarban. Now Bawalis also collect Nypa, and other non-wood products e.g. mele grass (*Cyperus javanicas*) ulu grass (*Imoerata cylindrical*), and also give labor to Mawalis. Fishers also collect fish fry, timber and Nypa during harvesting season. Children and wives of fishers collect shrimp fry, snail and oyster. Taking the learning from the SLD, livelihood groups have been broadly classified in to three group as; Bawali, Mawali, and Fisher. In Table 4.1 identified livelihoods are listed with their types of extracted resources and harvesting seasons.

Table 4.1: Sundarban dependent livelihood

Livelihood group (*translated in English*)	**% (From SLD)**	**Extracted resources**	**Harvesting season**
Bawali (wood cutter)	55	Timber,	December to March
		Nypa palm, grass for matting, reed for fencing	Mid November to mid March
Mawali (honey collector)	15	Honey, bee wax	March to June
Jele (fisher)	30	Fish, prawn fry, oyster, snail, crab	Round the year

4.2 Livelihood Capitals

In this study, livelihood has been defined in the notion of five capitals following the sustainable livelihood framework. Livelihood capitals have been categorized in to five groups as; natural, physical, financial, social and human. For all of the livelihood

groups, Sundarban is the vital capital but recognized differently. Social and physical capitals play an important role to increase livelihood resilience. Livelihood capitals were identified through SLD by using resources mapping tool. Figure 4.1 shows the resource map of Sundarban dependent livelihood group of Amadi union. In Table 4.2, livelihood capitals of different livelihood groups are listed with ranking given by them during SLD.

Table 4.2: Livelihood capitals of Bawali, Mawali and Fisher

Natural capital					
Bawali		Mawali		Fisher	
Capital	Rank	Capital	Rank	Capital	Rank
Sundarban	1	Bee (*Apis dorsta*)	1	River	1
Agricultural land	2	Honeycomb	2	Brackish water zone	2
River	3	Sundarban, Flowers of trees	3	Sundarban	3
		Agricultural land	4	Agricultural land	4
		River	5		
Financial Capital					
Bawali		Mawali		Fisher	
Capital	Rank	Capital	Rank	Capital	Rank
Timber trees	1	Honey	1	Fisheries	1
Golpata	2	Bee wax	2	Nets	2
Mele grass, Permits, Boat license certificate (BLC)	3	Permits, Boat license certificate (BLC)	3	Boat, Permits, Boat license certificate (BLC)	3
Loan from local money lender	4	Loan from local money lender		Loan from local money lender	4
Common for all (Bawali, Mawali, Fisher)					
Physical		Social		Health	
Capital	Rank	Capital	Rank	Capital	Rank
House	1	Family network	1	Health	1
Forest department	2	Social organization	2	Physical labor	2
River for navigation	3	Mosque/ temple	3	Experience in Sundarban	3
Road network	4	Local markets	4	Skill	4
Cyclone shelter, Embankment	5	Forest guard	5	Knowledge	5
Health complex	6	Coast guard	6		
Educational institute	7	Mosque/temple committee	7		
Buoys, lights, pontoon	8	Market committee	8		

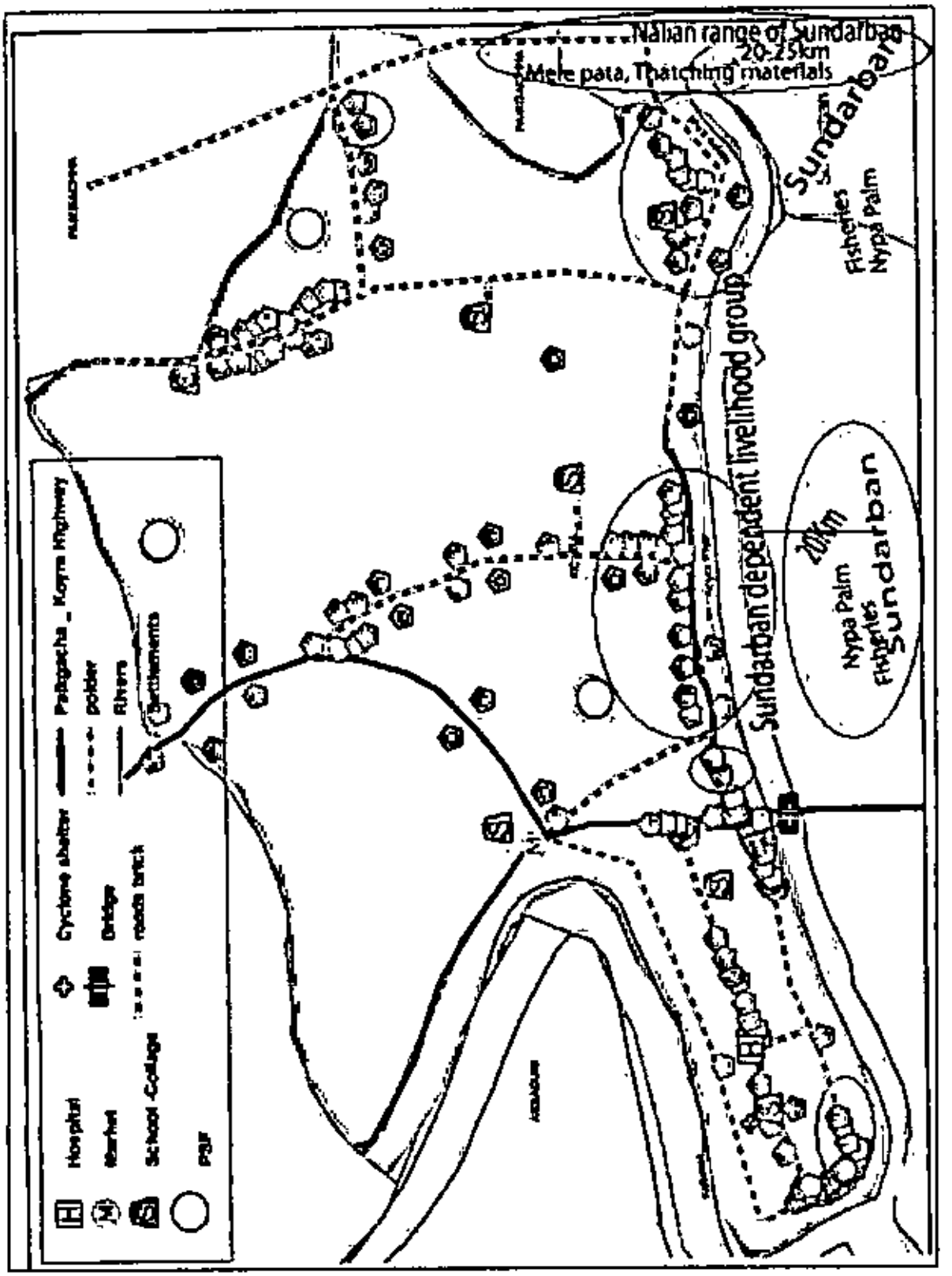

Figure 4.1: Resource map of Sundarban dependent livelihood group of Amadi (Modified after SLD)

4.3 Impact of Salinity Intrusion on Livelihood Capitals

Climate change induced salinity intrusion is likely to change the productivity of Sundarban that will affect the livelihood capitals of Bawalis, Mawalis and fishers. Different livelihood capitals are likely to be impacted in different ways. Livelihood capitals to be affected in response to changes of Sundarban Mangrove System have been analyzed through hazard development chain in the following sections. The hazard development chains describe the salinity intrusion hazard as a sequential event. Also the control stages have been identified. The control stages describe generically as well as by the specific control options to break the pathways between hazard states or to reduce the evolving hazards.

4.3.1 Impact on natural capital

Climate change induced salinity intrusion is likely to affect the productivity of the Sundarban. A significant decrease in regeneration and growth is noticed with an increase in salinity (Siddique et. al., 2001). The germination of seedlings, metabolic activities are dependent on salinity. Salinity reduces the productivity, growth of the mangrove timbers (McLeod and Salm, 2006; Siddique et. al., 2001; Ellison et al., 2000). The top dying disease, root rot disease in Sunduri, Sunduri-Gewa and Gewa-Sunduri typed forest of Sundarban is due to increased salinity and fungal infection (Rahman, 1998; CEGIS 2006). It is speculated that productivity and regeneration will be reduced by 13% and 27 % respectively with 88cm SLR induced salinity intrusion (Rahman, 2008). Salinity intrusion cause change in fish composition and shifting of fishing zone. These changes in productivity ultimately affect other livelihood capitals. The hazard chain (Figure 4.2) shows the hazard development stages of the salinity intrusion. The hazard development chain discloses the climate change induced salinity intrusion hazard as a sequential events. Four control stages have been identified and are linked vertically to the pathways between hazard states. The control stages can break the chains or slow down the hazard development processes.

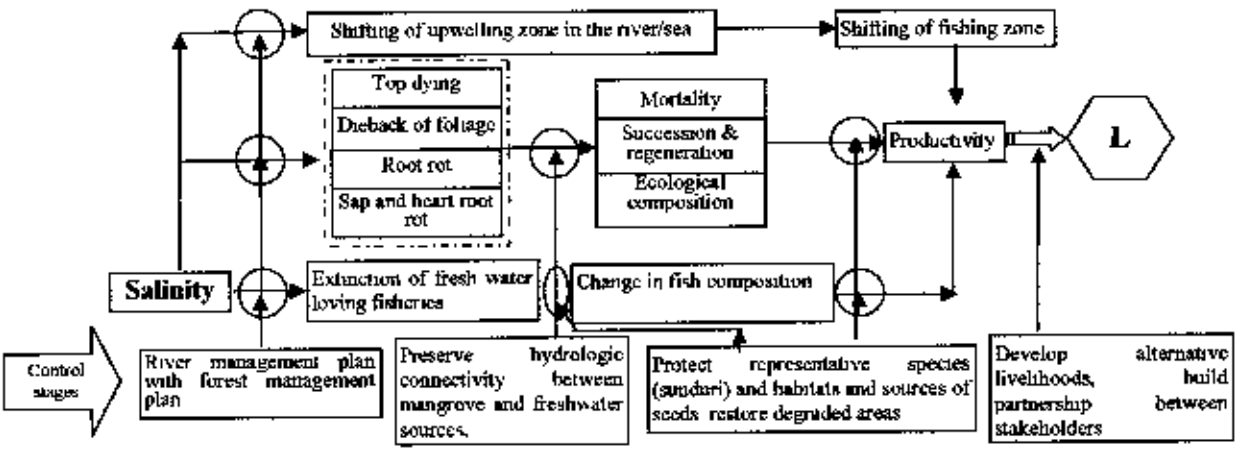

Figure 4.2: Hazard development chain of salinity intrusion on natural capital

4.3.2 Impact on financial capital

Production from the forest has been reduced over the decay. Figure 4.3 and Table 4.3 shows the gradual reduction in the production of extractable resources accounted by the forest department. It is explicitly showed that amount of the extracted Nypa palm and fish catch has been reduced significantly.

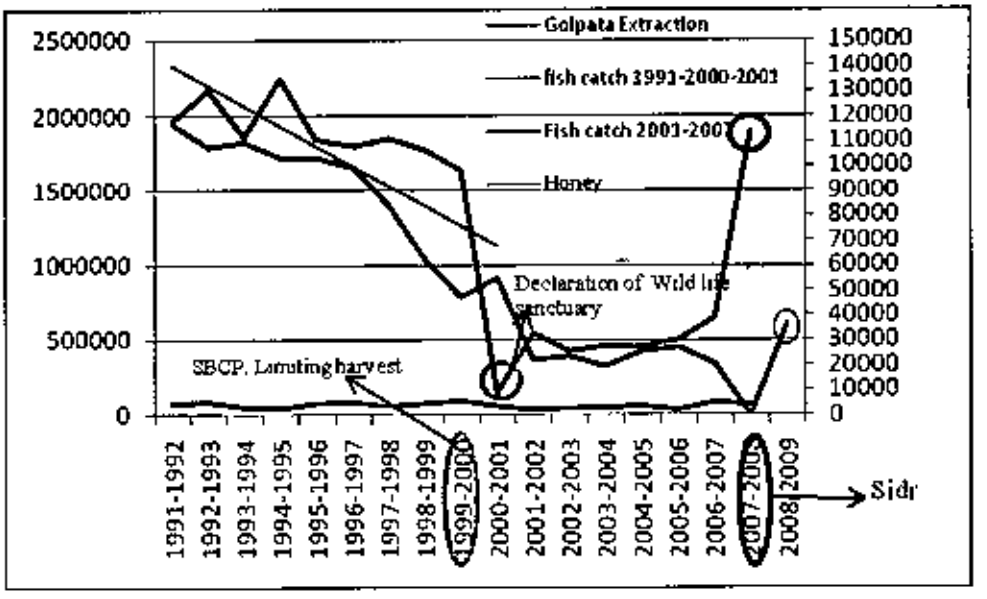

Figure 4.3 Trend of extraction of forest resources (source: FD)

Table 4.3: Extracted forest resources form 1991-2009

Harvesting Year	Nypa palm (golpata) in ton	Honey in ton	Fish in ton	Remarks
1991-1992	1940505	4264	117901	
1992-1993	1789985	4890	130407	
1993-1994	1824252	2841	111832	
1994-1995	1722241	2320	134800	Amendments of new forest policy
1995-1996	1720346	4278	110689	
1996-1997	1648879	5155	107742	
1997-1998	1392431	3489	111076	
1998-1999	1033080	4272	106619	
1999-2000	**782425**	5552	**97938**	SBCP project (Limiting harvesting), Declaration of World life sanctuary
2000-2001	917121	3465	**8352**	
2001-2002	367770	1807	32555	
2002-2003	392173	2570	25520	
2003-2004	326464	3122	27495	
2004-2005	429182	3466	27021	
2005-2006	453375	1938	29963	
2006-2007	342715	4961	38999	
2007-2008	0	3740	113612	Cyclone Sidr: boosted fish catch amount
2008-2009	603169	continuing	continuing	1 yr restriction of harvesting increase Nypa production

(Source: FD)

Forest production (Nypa palm and fish) were declining gradually till 1999, then drastically reduced due to induction of new policy through Sundarban Diversity Conservation Project (SBCP) (1999-2005). Data of forest department suggests that honey production have not been changed significantly, while Mawali noticed reduction of number of honey comb and amount of honey. In case of fish catch the amount drastically reduced during 2000-2001 due to prohibition of fish catch in wild life sanctuary (139700 ha) and 18 khals after declaration of three wild life sanctuaries. Harvesting of timber products was banned during 1979-80. Harvesting of fuel woods, reeds and other thatching materials (except Nypa palm) have been restricted in response to declining status of the forest. Thus the livelihoods dependent on Sundarban mangrove are affected due to changing climate by two ways; (i) reduction of productivity and (ii) Imposed policy of the government. It is expected that the forest policy will be more rigid in near future. In Figure 4.4 impact of salinity intrusion on financial capitals has been shown throngh hazard development chain. The event salinity intrusion is likely to cause reduction of food security, livelihood security and ultimately cause health hazard. Five control stages also have been identified, which are vertically linked to the chain pathways between hazard states (Figure 4.4). Each of these control stages can break the linked pathway or slowdown the hazard development process.

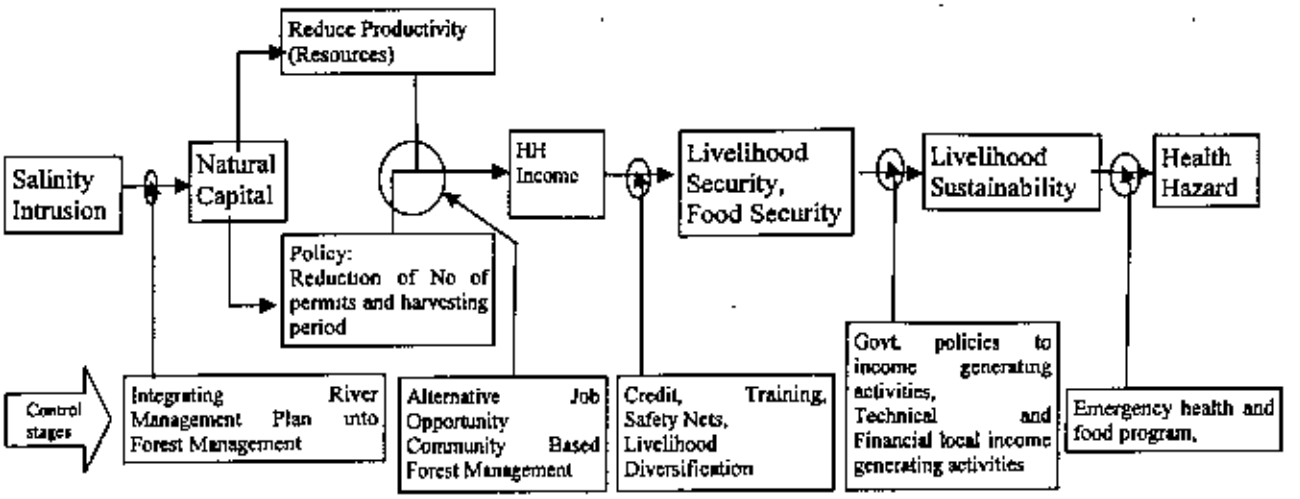

Figure 4.4: Hazard development chain of salinity intrusion on financial capital

4.3.3 Impact on physical capital

Salinity intrusion shrinks the fresh water resources (both ground water and surface water). Groundwater dependent drinking water systems are vulnerable to climate change induced salinity intrusion. Large ponds with pond sand filter, rain water capturing system are resilient to salinity intrusion. Coastal embankment will protect inland surface water and agricultural lands. Reduction in financial capital reduces the ability to spend in house repairing, which will make vulnerable to other disaster. Figure 4.5 explicitly describes the hazard development chain of salinity intrusion on physical capital. Four control stages have been identified to break the chain of evolving hazard.

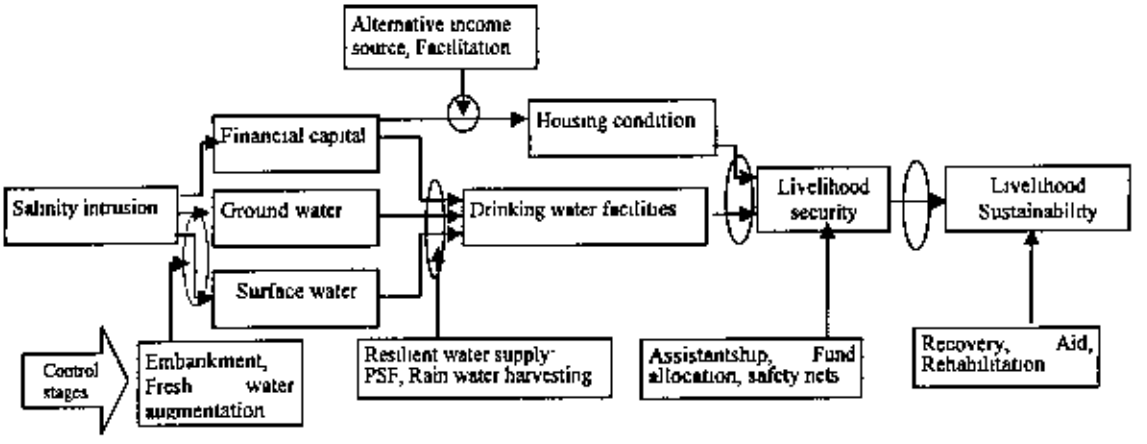

Figure 4.5: Hazard development chain of salinity intrusion on physical capital

4.3.4 Impact on human capital

Reduction of income opportunity will force the people to switch their livelihoods. Local people reported that some of them already migrated to the cities for seeking income opportunities. This migration of experienced manpower will cause shortage of skilled labor for harvesting of forest resources. Unskilled person have no knowledge on how to harvest forest resources in sustainable manner. Involving unskilled person will make the harvesting system unsustainable which will affect forest sustainability. Impact on forest sustainability will also affect other livelihood capitals.

The most perceived risk on human capital is attack of Royal Bengal Tiger. Frequency, location, and time analysis of incident of tiger attack (JJS, 2003) disclose that the incident of tiger attack is more frequent during dry season (December-June), when river water salinity in Sundarban is high. Tigers enter the human settlement due to scarcity of fresh water and food shortage in the forest. The study also shows that the incident is more frequent in the moderate and high saline zones of the Sundarban. The incident is becoming more frequent and is expected to be severe in all over the Sundarban impact zone due to climate change induced salinity intrusion. Figure 4.6 describes the possible impact of climate change induced salinity intrusion on human capital through hazard development chain. Six control stages have also been identified to break the chain of evolving hazard or to slowdown the hazard development process.

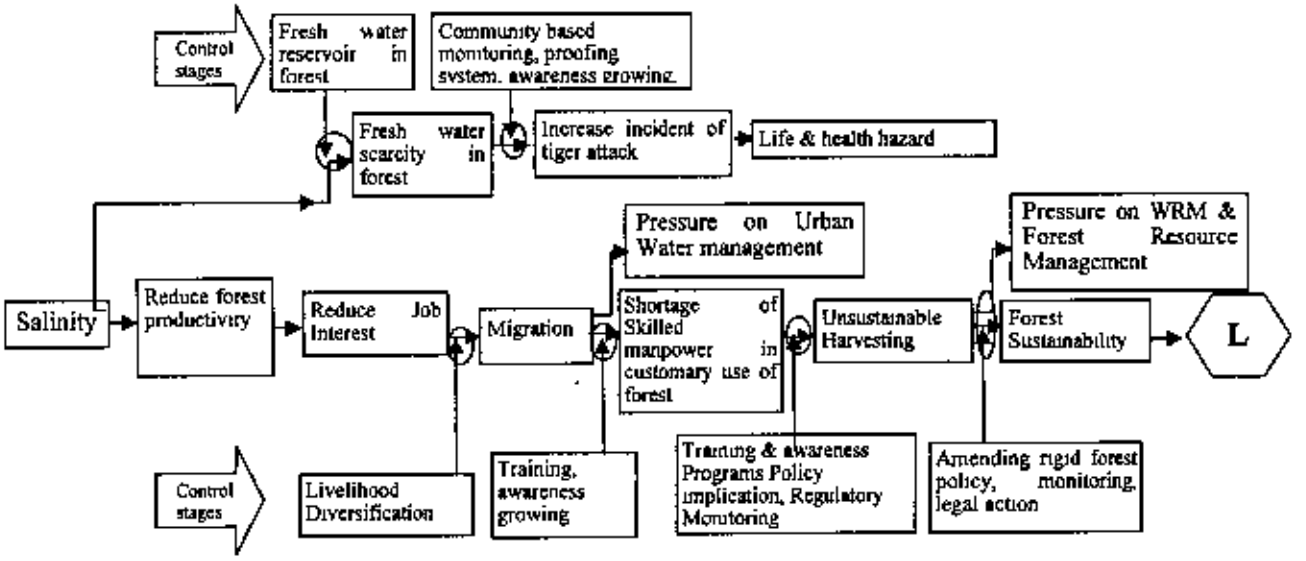

Figure 4.6: Hazard development chain of salinity intrusion on human capital

4.3.5 Impact on social capital

Social capital filters the risk. Social capitals are most important for enhancing livelihood resilience. Social capitals are institutions, safety nets, social networks, policies, rules and regulations etc. which are related and co-acting with other livelihood capitals. Community based forest management, alternative income opportunities, credit systems, government supported assistantship programs are acting as resilient measures in different stages of hazard development chain. Effectiveness and function of other livelihood capitals especially physical, human and financial capitals depend on function of social capitals.

CHAPTER FIVE

LIVELIHOOD RESILIENCE ASSESSMENT MODEL

5.1 Structuring Indicator Framework for Assessing Livelihood Resilience

Building on sustainable livelihood approach, the indicator framework has been delineated into five livelihood capitals; natural, physical, financial, human and social capital. Livelihood resource and its dynamic attributes (robustness, redundancy, rapidness and resourcefulness) were captured by setting indicator dimension productivity, snstainability and risk (discussed in detail in methodology). The indicator framework was developed in three steps i.e., (i) theoretical approach through reviewing literature, (ii) understanding relationship between livelihood and mangrove through SLDs and (iii) practicality through self judgment. Sixty indicators were chosen from available studies on community/livelihood resilience (See Appendix I). After taking feedback from SLD, these preliminary chosen 60 indicators were screened to 33 indicators (see Appendix II). And finally 24 indicators were selected through self judgment based on practicality (see Appendix III). The indicators are measured in qualitative scale described by the word scenarios (see Appendix IV). In the following sections, the theoretical basis, screening process and the final indicator framework are described.

5.1.1 Natural capital

Theoretical basis

As the livelihood of the community dependent on Sundarban is farmed by the natural capitals, so its contribution to resilience is major. Climate change induced salinity intrusion will directly affect the natural capitals. Forest productivity largely depends on salinity. Landward propagation of salinity front decreases the productivity (CEGIS, 2006, Ellison, 2000). Low productivity also makes low resilient livelihood. Sunduri is very sensitive to salinity. Sunduri and Gewa typed forest indicate most diversified and productive regiou, also they are the key economic resources which are very sensitive to salinity (CEGIS, 2006; Kabir and Hossain, 2008, Hossain, 2008). Sunduri-Gewa typed forest is subject to top dying diseases due to salinity intrusion that put pressure on forest productivity and sustainability. Forest management which brings together the collaborative and adaptive practices in management approach, not only solves resource problems, but also aspires to foster ecologically sustainable livelihoods (Plumer and

Armitage, 2007). Corruption in the management process affects the institutional stability (Vincent, 2004) that malfunctions the sustainable forest management plan.

Screening

Preliminarily 12 indicators were chosen for natural capital through theoretical approach (see Appendix I). After the second stage, these 12 indicators were screened to 9 (see Appendix II). At first stage two criteria were chosen (i.e., effectiveness of the river management in Sundarban and effectiveness of the forest management) to indicate the sustainability of the natural capital. Through SLD, it was realized that effectiveness of Sundarban forest management is pinned with river management and that's why one criteria i.e., effectiveness of forest management was chosen in later to indicate the sustainability of the natural capital. 'Integration of river management plan' and 'measures taken to combat salinity intrusion' were selected to address the effectiveness of forest sustainability. 'Improvement of forest health status' and 'production increase' were rejected because 'integration of river management' and 'measures taken to combat salinity intrusion' also gives sense of effective forest management.

Finally, 6 inthicators were chosen (Table 5.1). At final screening 'corruption of forest stuff' was rejected. Corruption weakens the forest management but this is another issue and is not directly related with climate change induced salinity intrusion. Also use of poison for fishing was screened out due to having no relation with salinity intrusion.

Final indicator framework

Table 5.1: Natural capital indicators for assessing livelihood resilience

Dimension	Criterion	Indicator
Natural capital		
Productivity	Forest health status	Propagation of salinity front
		Status of Sunduri typed forest
Sustainability	Effectiveness of forest management plan to combat salinity intrusion	Integration of river management in forest management plan
		Measures taken to combat salinity intrusion
		% of harvester follwoing the harvesting rules
Risk	Pressure on forest	Spreading of top dying disease

In the final framework, 'criterion of forest health status', 'effective forest management' and 'pressure in forest' were selected. The qualitative indicators for forest health status were chosen as 'propagation of salinity front' and 'status of Sunduri typed forest'. Forest health of Sundarban depends on salinity. Ecological health of the forest is better

in low saline region. Sunduri typed forest dominates in low saline region and represents good ecological health and richness in biodiversity. Sunduri is the most salinity sensitive tree in Sundarban. Forest sustainability as well as resiliency relies on effective forest management. 'Incorporating river management plan', 'measures taken to combat salinity intrusion', and 'following of harvesting rules' were chosen to address sustainability of the forest that gives ecosystem resilience as well as livelihood resilience. Top dying diseases of Sunduri tree is an epidemic in Sundarban which is caused by excess salinity. Top dying disease is likely to be spreading frequently due to climate change induced salinity intrusiou. The epidemic of top dying disease will put pressure on natural capital (i.e., Sundarban) of the livelihood groups that weakens their livelihood resilience.

5.1.2 Financial capital

Theoretical basis

Community resilience not only depends on the volume of financial capitals but also on their diversity, especially income or livelihood diversity (Norris et al., 2008). Especially in case of Sundarban, where climate change induced salinity intrusion is causing change in forest health and productivity, livelihood diversification is an important resilient measure. Dependency on natural resources decreases resilience of livelihood (Adger, 2008; Cutter et al., 2006). Training and skill of diversifying livelihood, access to other income generating activities, employment generation, savings, and access to credit system increase livelihood resilience (Moench and Dixit, 2004; Heltberg et al., 2009).

Screening

Preliminary 'scope of alternative jobs', 'percentage of population have agricultural land/ pond' were in the framework, but these two were replaced by access to non forest based livelihood options to indicate all means of alternative livelihood options. One may not have any land or household resources but they can generate their income from local resource base (e.g., serving labor, pulling van etc). Strictness of Microfinance institute (MFI) was screened out through SLD. System and source of credit also indicate the rules of the credits. No specification is necessary for MFI, moreover the target populations are not involved with any MFI.

'Access to early warning system' was also screened out in final framework. Access to early warning system is important for livelihood but is not sensitive to salinity intrusion. Followed by the understanding of the relationship of indicators with salinity intrusion and livelihood option, 5 indicators (Table 5.2) were chosen through two times screening of preliminarily identified 12 indicators (Appendix I and II).

Final indicator framework

Table 5.2: Financial capital indicators for assessing livelihood resilience

Dimension	Criterion	Indicator
Financial capital		
Productivity	State of forest production	Timber and nonwood/fish/honey production
	Degree of livelihood deversification	Having options of non forest based livelihood
	Credit system	Source and system of credit
Sustainability	Support from GO and NGO	Support from GO/NGO in income generating activities
Risk	Instability of govt approach	Sudden declaration of banning harvest in Sundarban

In final framework, state of forest production, degree of livelihood diversification, source of credit, support from GO and NGOs and instability of government approach criterions were considered. Forest resources are important financial resources for all livelihood groups. Timber production, non wood production, fish production, honey production is sensitive to salinity intrusion. Climate change induced salinity intrusion will reduce the forest productivity. In response to reduced forest productivity, option of non forest based livelihood strengthens livelihood resilience to salinity intrusion.

Sources and system of the credit is very important for Sundarban dependent livelihood groups. During the harvesting season they take loan from local money lender with condition that they have to sell the extracted resources to local money lender. Local money lender also fixes the price which is below the market price. To overcome this loss, harvesters do overextraction the resources and disobey the management rules. Thus the system of the credit persuades them to practice unsustainable harvesting which also collapse the resilient measures taken by forest department in response to salinity intrusion. So in the line with productivity reduction, strictness of the credit system weakens the resilience.

Supports from GO and NGOs in income generating activities for non forest dependent livelihood will give the sustainability of the financial capitals as well as their livelihood resilience.

Livelihood opportunity in Sundarban is to be affected by salinity intrusion in two ways i.e., by reducing productivity and policy imposed by the governments. Government has already limited the harvesting period. Moreover in response to any extreme event (like cyclone, diseases spreading etc) government sudden close the harvesting permits in Sundarban. Event of disease spreading will increase due to salinity intrusion so in future Government will frequently close the harvesting permits. This instable approach of the Government weakens livelihood resilience.

5.1.3 Physical capital

Theoretical basis

Coastal defense structure increases resilience of the community to respective disaster (Cutter et al., 2008). The embankment that is to protect other financial resources (agricultural land, ponds etc) from salinity intrusion has influence on livelihood resilience. Transportation and communication increase resilience (Cutter et al., 2008), keep links with the neighbor cities and urban areas, and gives potential of alternative livelihood. Option and access to drinking water are important for livelihood resilience.

Screening

Through theoretical approach, 12 indicators were selected relevant to livelihood resilience (Appendix I). Then these 12 indicators were screened to 3 based on sensitivity to salinity intrusion (Table 5.3). House hold ownership, housing condition, condition of transportation system, remoteness from district city, availability of paved roads were screened out to keep the framework concentrated on climate change induced salinity intrusion.

Final framework

Table 5.3: Physical capital indicators for assessing livelihood resilience

Dimension	Criterion	Indicator
Physical capital		
Productivity	Drinking water resources	Option of drinking water
Sustainability	Coastal defence structure to combat salinity intrusion	Condition of coastal embankment/polders
Risk	Failure of coastal defence structure	Failure of coastal embankment (How often)

Fresh water resources for drinking purpose are important physical assets. Large ponds, pond sand filters and hand pump tube wells are the main options of the fresh water. Salinity intrusion will limit the options for fresh water. Human settlements in the village near the Sundarban are protected from salinity intrusion by polder or embankments. These coastal structures strengthen the livelihood resilience by protecting livelihood capitals. Illegal breaches, failure during extreme events (i.e., cyclone, flood, high tide) weaken the salinity protection system as well as livelihood resilience.

5.1.4 Human capital

Theoretical basis

Resilience also depends on education, knowledge and awareness of the community (Moench and Dixit, 2004; Cutter et al., 2008; Heltberg et al., 2009). Knowledge on risk and learning from it make the livelihood groups more resilient. Adaptation and coping mechanism are the manifestation of learning from risk (Cutter et al., 2008). Training and awareness programs addressing risk, and coping mechanism influence livelihood resilience (Heltberg et al., 2009). Occupational hazards (attack of sea pirates and tiger) have also influence on livelihood resilience especially in case of Sundarban.

Screening

Preliminarily, most of the indicators in this domain were quantitative but later these were transubstantiated into qualitative form that reduced the number of indicators. For assessing productivity of human capital, 'numbers of training program launched in last five year', 'percentages of population have training', were chosen preliminarily, then these were replaced by 'knowledge on non forest dependent livelihood' because our aim was to address their ability to generate income from option rather then mangrove forest. Again rate of out migration of labor skilled in forest resource harvesting was screened out in final framework. Out migration of skilled labor is putting pressure on sustainable forest harvest but it is tough to separate salinity intrusion driven out migration. Followed by the significance, relationship with salinity intrusion and data availability the indicators were screened and finally 6 indicators were chosen.

Final framework

Table 5.4: Human capital indicators for assessing livelihood resilience

Dimension	Criterion	Indicator
Human		
Productivity	Knowledge	Knowledge on non forest dependent livelihood
Sustainability	Local understanding of risk	Knowledge on climate change
		Level of adopted coping mechanism
Risk	Occupational hazzards	Attack of Royal Bengal Tiger
		Attack of sea pirates

As salinity intrusion is likely to reduce livelihood opportunity in forest by reducing prodnctivity, training on non forest based livelihood will give resilience. Understanding the risk of salinity intrusion will inake the community to change their livelihood strategy in response to salinity intrusion induced change in forest productivity. Knowledge on salinity intrusion and practiced copping mechanism give sense on their understanding of risk of salinity intrusion.

Occupational hazard like attack of the tiger and sea pirates weakens the livelihood resilience. Attack of the Royal Bengal Tiger will increase due to salinity intrusion. Generally tigers enter the human settlements, harvester's boat or attack the harvesters when they have food shortage, fresh water scarcity, and habitat destruction. Climate change induced salinity intrusion will exacerbate the food shortage, fresh water scarcity, and destruct their habitats.

Attack of the sea pirates is not related with salinity intrusion. But this is very important for the livelihood strategy of the Sundarban dependent livelihood. Livelihood gronps have to give a certain amount of money/extracted resources to the pirates during each trip of harvesting. Each trip they have to face at least two/ three group of pirates. To overcome this loss, the harvesters have to disobey the management rules of the forest departments and overextract the resources. Resilience of the natural capital to salinity intrusion depends on the sustainable harvesting of the resources that is affected by the overharvesting and disobeying of rules persuaded by the sea pirates.

5.1.5 Social capital

Theoretical basis

Social capital offers ways to understand the role of fundamental social attributes that contribute towards building capacity for social collectives and individuals to respond to climate change (Pelling and High, 2005). Key components of resilience are likely to include leadership and insight, sustained mobilization of national and international aid, cultural and ecological diversity, development of multi-scale social networks, and the resolution of local civil unrest (Hughes et al., 2005). According to DROP (Disaster resilience of place) model (Cutter et al., 2008), exogenous factors such as federal policies and state regulations do exert powerful influence on resilience at the community level. Social safety nets, community organizations, social initiatives, education, awareness, knowledge have influence on livelihood resilience (Moench and Dixit, 2004; Cutter et al., 2008; Heltberg et al., 2009). Pre-existing organizational networks and relationships with community are the key to rapidly mobilizing emergency and ongoing support services for disaster survivors (Norris et al., 2008). Communities have some adopted mechanism to manage the effect of salinity intrusion on forest with aspire to increase livelihood resilience. Political shaping of the social organizations and government assisted programs reduce the resilience by limiting the common access to those programs.

Screening

Twelve indicators selected through theoretical approach (Appendix I) were screened to six. Change was also done in indicator criterion. The criteria 'institutional structure' was screened out and reciprocity was inducted. Reciprocity indicates mutualism of institution. 'Reciprocity among GO, NGOs and community in mitigating salinity intrusion risk' was chosen instead of 'interrelationship between GO and community' and 'interrelationship between NGO and community' which were not focused on salinity intrusion issue. Again existence and function of social organization were two different indicators of social network, in later which were replaced by 'involvement of social organization in mitigating salinity intrusion risk'. Preliminarily selected indicators were sort of general which in later were made focused on salinity intrusion risk mitigation.

Final framework

Table 5.5: Social capital indicator for assessing livelihood resilience

Dimension	Criterion	Indicator
Social capital		
Productivity	Reciprocity	Reciprocity among GO, NGO and community in mitigating risk of salinity intrusion
	Social network	Involvement of social org, in mitigating risk of salinity intrusion
Sustainability	Community initiated forest management in response to salinity intrusion	Level of community initiated forest management to mitigate risk of salinity intrusion
		Livelihood assistantship program launched by gov during banning period
Risk	Local politics	Political influence on social organization

Mobilization and modification of social capital strengthen other capitals to mitigate the risk. Institutional reciprocity, performance and status of social network, safety nets, and community initiated adaptation mobilize the social capitals. Involvement of GO and NGOs with community in the issue of mitigating risk and impact of climate change induced salinity intrusion indicate institutional reciprocity. This institutional reciprocity helps the community to recover from vulnerability, as well as increases livelihood resilience.

Social organization plays an important role in mitigating risk by initiating modification and mobilization of the other capitals. Actions of social organization to recover the losses of income potential incidental to salinity intrusion increases livelihood resilience. Social organization keeps link with npper tiers (decision makers, policy makers, government officials) of the society. But political shaping makes the social organization ineffective to function in vulnerability recovery process. Sundarban dependent livelihood groups, who are susceptible to be affected by salinity intrusion, are socioeconomically vulnerable and least empowered. Political shaping of the social organization limits accessibility of vulnerable livelihood group in getting benefits.

5.1.6 Indicator typology

For better understanding the relationship of the chosen indicator with livelihood capitals, the indicators are arranged into three groups (Table 5.6). Indicators that are related to salinity intrusion are salinity sensitive, and indicators that strengthen and weaken other capitals are grouped as capital strengthening and capital weakening respectively.

5.1.7 Weighing of the indicator

The weights of the indicators are shown in Table 5.6. Weights were assigned through SLD process. Weights are given in the scale of 5.

The weights of the natural capital indicators are ranging from 3 to 5. 'Status of Sunduri typed forest' and '% of harvester following harvesting rules' have highest weight. Because, Sunduri typed forest represents the most diversified and resourceful forest type, and sustainable harvesting depends on obeying the harvesting rules. Spreading of top dying diseases has weight, 3 despite of highly sensitive to salinity intrusion. Because, top dying disease affects only Sunduri tree which is not considered as economic resources by the livelihood group.

In case of financial capitals, 'forest production' 'support from GO/NGO in income generating activities', and 'sudden banning of harvest' have highest weight, 5. Highly sensitivity of forest production to salinity intrusion, necessity of GO/NGOs' supports in non forest based income generation, and unstable income due to sudden banning of harvest are the prime reasons that make the weightage of these indicators highest.

The highest weighed indicator in the domain of human capital is 'attack of sea pirates' (weightage 5) that puts risk of health hazard and financial loss. 'Knowledge on non forest dependent livelihood' and 'level of adopted coping mechanism' have weight 4 because of relevancy with income generation activities. Knowledge on non forest dependent livelihood is necessary to opt alternative livelihoods and adopted coping mechanism strengthens the other livelihood capitals to withstand to shocks of salinity intrusion.

In case of physical capital, option of drinking water bears the highest weight 5, because of being highly sensitive to salinity intrusion, and important livelihood capital. 'Reciprocity among GO, NGO, and community', and 'livelihood assistantship program' are the highest weighed indicators (weight 5) in the domain of social capital that strengthen the strategy and action of risk mitigation of salinity intrusion.

The weights of the indicators also give a directive of adaptation strategy. The indicators having highest weight should be given high priority during formulation of adaptation strategy to enhanced livelihood capitals.

Table 5.6: Typology and weights of the indicators

Indicator	Typology			Weightage (from SLD)
	Salinity sensitive	Capital Strengthening	Capital weakening	
Natural capital				
Propagation of salinity front	■			4
Status of Sunduri typed forest	■			5
Integration of river management in forest management plan		■		4
Measures taken to combat salinity intrusion		■		4
% of harvester follwoing the harvesting rules		■		5
Spreading of top dying disease	■			3
Financial capital				
Timber and nonwood/fish/honey production	■			5
Having non forest based livelihood option		■		4
Source and system of credit		■		4
Support from GO/NGO in income generating activities		■		5
Sudden declaration of banning harvest in Sundarban	■			5
Human capital				
Knowledge on non forest dependent livelihood		■		4
Knowledge on climate change		■		3
Level of adopted coping mechanism		■		4
Attack of Royal Bengal Tiger	■			3
Attack of sea pirates			■	5
Physical capital				
Option of drinking water	■	■		5
Condition of coastal embankment/polders		■		4
Failure of coastal embankment (How often)			■	3
Social capital				
Reciprocity among GO, NGO and community in mitigating risk of salinity intrusion		■		5
Involvement of social org. in mitigating risk of salinity intrusion		■		3
Level of community initiated forest management to mitigate risk of salinity intrusion		■		3
Livelihood assistantship program launched by gov during banning period		■		5
Political influence on social organization			■	3

5.2 Employing the Indicator Framework

The indicator framework was made operational by developing word scenarios for each of the indicators. Word pictures are the description of the asset circumstances. Word pictures of each indicator outline 'best case' to 'worse case' snapshot of resilience. Values were assigned as 1 to 5 for worst to best case scenarios. These word scenarios were developed in a participatory manner through SLD. Then an assessment sheet was prepared containing word scenarios with respective indicators for each of the five capitals. This assessment sheet was followed to collect data through SLD. In the Appendix IV the word scenarios of the indicator framework are attached.

5.3 Participatory Model for Assessing Livelihood Resilience

The livelihood resilience defined for this study as the ability of livelihood group to buffer the vulnerabilities, to withstand the shocks, to recover the impacts, and to prepare for future vulnerabilities by taking continual learning from vulnerabilities. This resilience depends on the capacity of livelihood capitals to act aforementioned function. Followed by the indicator framework, livelihood resilience has been defined as the networked capacity of the five livelihood capitals and the indicators tabulated in the Table 5.1 are the determinants of livelihood resilience. This networked capacity of the livelihood capitals is shown through a conceptual model in Figure 5.1, where the indicators mentioned in Table 5.1-5.5 (also Appendix III) exhibit the livelihood resilience.

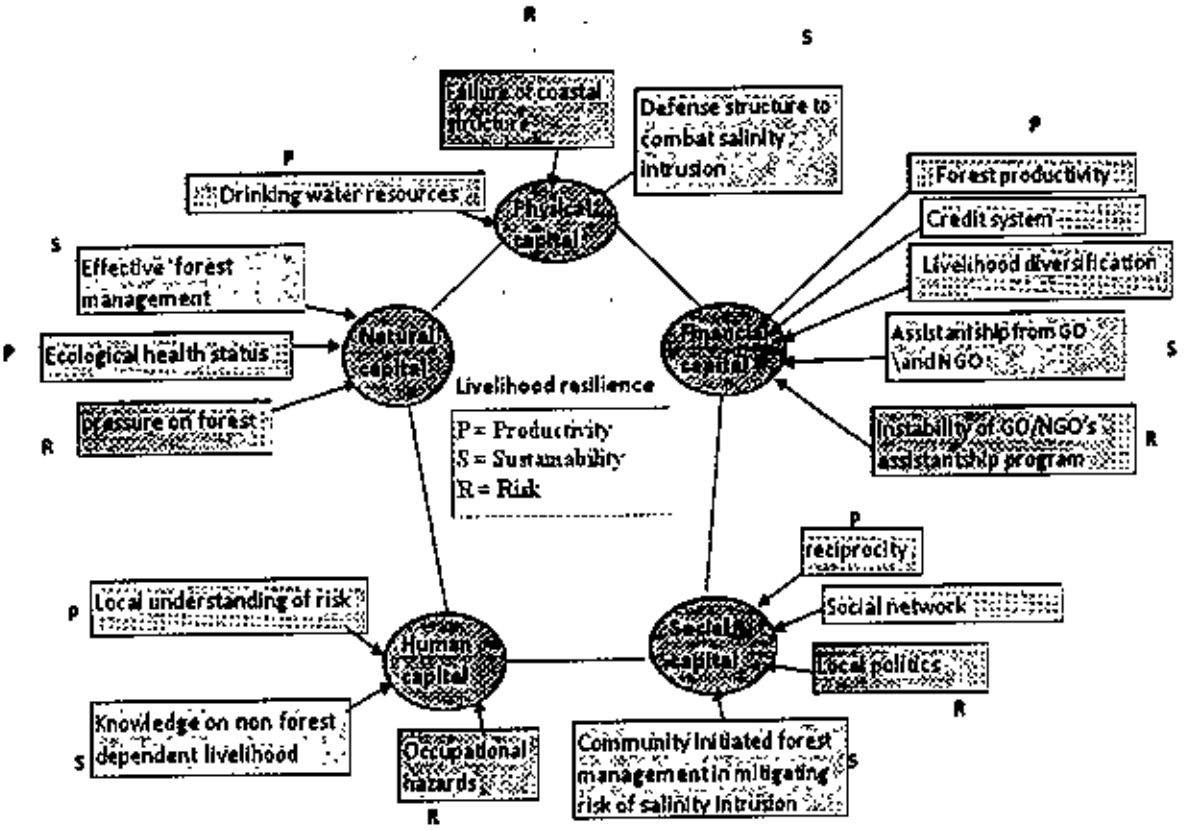

Figure 5.1: Conceptual model for assessing livelihood resilience

The model is translated into algebraic form for quantification of livelihood resilience as given in equations 3.1-3.6 in chapter three. The quantification of the livelihood resilience is discussed in the next chapter.

CHAPTER SIX

LIVELIHOOD RESILIENCE OF BAWALI

6.1 performance of Livelihood Capitals in Contributing the Livelihood Resilience of Bawali

Resilience of the livelihood capitals were analyzed and assessed following the assessment sheet through SLD with Bawali. In the assessment sheet the resilience scores were ranged from 1 to 5, where score 1 indicates the poor contribution in livelihood resilience, and 5 indicates the best contribution which means resilient livelihood. In the following sections the performance and contribution of livelihood capitals are discussed.

6.1.1 Natural capital

Table 6.1: Indicator score of natural capital

Ind. no	Indicators	Matched word scenarios	Score (out of 5)
N1	Propagation of salinity front	Salinity have affected in the zone of Sunduri forest	2
N2	Status of Sunduri typed forest	Salinity intrusion is affecting the Sunduri tree, height has been reduced, in fresh water zone, In moderate saline zone Sunduri typed forest is shrinking	3
N3	Integration of river management in forest management plan	Not mentioned in plan	1
N4	Measures taken to combat salinity intrusion	Not mentioned in plan	1
N5	% of harvester follwoing the harvesting rules	10-20%	1
N6	Spreading of top dying disease	Disease affects moderate and high saline zone. Some parts of fresh water zone is also affected	2

The scores of the natural capital indicators are shown in Table 6.1 with matched word scenarios of the assessment sheet. Increasing propensity of river water salinity in Sunduri forest of moderate to fresh water zone makes the resilience score as 2 that indicate low resilience. Resilience score of the iudicator 'status the Sunduri typed forest' is 3, which is moderate. This is because, in fresh water zone, Sunduri type forest is showing quite good health. It is also reported that, the height of the Sunduri tree is reducing due to salinity increase in fresh water. Effectiveness of forest management plan is very poor. Each of the three indicator of this criterion gives resilience score only 1. The forest management plan without addressing the plan to control effect of salinity

intrusion, no consideration of river management and poor comanagement make the management plan poorly effective. Literary our forest management plan has switched from revenue growing to forest conservation but in practical, revenue collection is still practiced as a main function of forest department, and coupled with corruption unsustainable practice of forest resources extraction is continuing. Forest department is doing part of revenue collection, protection of Sundarban from illegal extraction and over extraction. Ecosystem health monitoring, water quality monitoring is the part of department of environment while river management is in under the anthority of water board. Each of the departments plans separately and has separate management strategy. Knowledge gap and lack of integration among the different department leads forest management and conservation to unsustainable situation. Moreover, very poor portion of the harvesters (15%) follow the harvesting rules.

6.1.2 Financial capital

Table 6.2: Indicator score of financial capital

Ind. no	Indicators	Matched word scenarios	Score (Out of 5)
F1	Timber and nonwood /fish/honey production	Small production that provide HH expenditure for 3-5 months	2
F2	Option of non forest based livelihood	Agricultural labor, option of daily labor round the year (or at least 8 months)/pulling van in local areas.	3
F3	Source and system of credit	Mohajon (local Money Lender) with condition: "Have to sell product to Mohajon at price fixed by Mohajon"	2
F4	Support from GO/NGO in income generating activities	Only financial/technical support, inadequate	3
F5	Sudden declaration of banning harvest in Sundarban	Frequently after high magnitude cyclone like Sidr, epidemic	3

Table 6.2 shows the resilience scores of the financial capital indicators with matched word scenarios. Indicator score of the forest production has been found to be 2, which indicates low forest production. Present forest production provides household expenditure of Bawali for 3-4 months. In response to reduced income from forest Bawalis have changed their livelihood strategy by extracting multiple resources form forest and increased non forest based income opportunity. Degree of livelihood diversification has been found to be 3, which is moderate. The seasonal calendar of livelihood activities (Table 6.3) describes diversification of their livelihood. Score for

the support from the GO and NGOs has been found as 3, that indicates moderate support in income generating activities. Resilience score of the credit system is 2, which indicates low resilience contribution in livelihood resilience. Government banks have no special scheme for forest resources extraction, as it has for other agricultural and small enterprises. Bawalis take loan from local money lender to manage harvesting cost, with rigid and unfavorable conditions that borrower have to sell their resources to Mohajon at price which is 25-30% lower than the market prices.

Table 6.3: Seasonal calendar of livelihood activities of Bawali (after SLDs)

Livelihood activities	12 Months											
	Baishakh (April-May)	Jaistha (May-June)	Asar (June-July)	Shrabon (July-August)	Vadro (August-Sept)	Arshin (Sept-Oct)	Katrik (Oct-Nov)	Aghrayan (Nov-Dec)	Poush (Dec-Jan)	Magh (Jan-Feb)	Falgun (Feb-March)	Chaitra (March-April)
Collection of fuel wood												
Nypa (Golpata) Collection from Sundarban												
Mele pata (Matting grass) collection from Sundarban												
Agricultural labor												
Daily labor												
Timber sawing												
Van pulling												
— • — • —	Unstable and discontinuous income opportunity											

6.1.3 Physical capital

Table 6.4: Indicator score of physical capital

Ind. no	Indicators	Matched word scenarios	Score (out of 5)
P1	Option of drinking water	Deep tube well, Pond with PSF (within village)	3
P2	Condition of coastal embankment/polders	Polder exist but management is poor, have illegal breaches in some places, will not retain during cyclonic event	3
P3	Failure of coastal embankment (How often)	After every 2/3 years,	2

The status of physical capital has been checked and matched with assessment sheet. The word scenarios and respective scores of the indicators are shown in Table 6.4. The table shows that the scores of the three indicators range from 2-3. Resilience score of the drinking water resources is 3 that indicate moderate resilience. This is because of having pond sand filter and low dependency ground water which is subject to salinity intrusion and arsenic contamination. These ponds or PSFs are not equitably distributed;

there are only 3-4 ponds with PSF in Amadi union. Moreover, management of these community pond and PSF are very poor and frequently go out of work.

The score of the 'coastal defense structure to combat salinity intrusion' has been found as 3 that inthicate moderate contribution in livelihood resilience. The villages adjacent to Sundarban are enclosed by polders to protect salinity intrusion. But shrimp farmers frequently make breaches or illegal inlets through the polders that weaken the earthen polders and cause damage during heavy monsoon (after each 2-3 years) or moderate intense cyclonic surges. The resilience score for the risk of failure of coastal embankment is 2 that indicate low resilience contribution. This is because of high risk of failure of embankment.

6.1.4 Human capital

Table 6.5: Indicator score of human capital

Ind. no	Indicators	Matched word scenarios	Score (Out of 5)
H1	Knowledge on non forest dependent livelihood	Labor, agricultural labor, seasonal trading business of agricultural products, and some knowledge on building construction works, boat making,	4
H2	Knowledge on climate change	Know but not clear. Heard from NGOs. Have heard about SLR and Inundation,	3
H3	Level of adaption mechanism	decreasing dependency on forest resource by diversifying livelihood, saving,	3
H4	Attack of Royal Bengal Tiger	In fresh water zone incident of tiger attack is increasing, and has increased in moderate saline zone	2
H5	Attack of sea pirates	Several times by different groups at each harvesting trip. There is a rule of giving fixed amount of money to each of the groups. Have security force but not active/adequate	2

Tbe status of the human capital has been analyzed by following assessment sheet. The matched word scenarios are tabulated in the Table 6.5 with respective scores. It shows that the resilience score of indicators range from 2 to 4. The knowledge on non forest based livelihood has score 4, which is highest in this domain and indicate resilience to some extent. Resilience score for the knowledge on climate change is 3, which is moderate. SLD reveals that Bawalis only heard about the possible sea level rise from different NGO workers but don't know what does it really mean. Resilience score for adaptation strategy is 3, which is moderate because, Bawalis are decreasing tbeir forest dependency. Attack of the tiger and sea pirates both put the high risk on human capitals and make the resilience score low. Increasing status of tiger attack in fresh water zone

gives resilience score as 2, which indicate low resilience. Present situation of piracy in forest makes the resilience score of the indicator: 'attack of the sea pirates' as low as 2. This is because of high risk of piracy in forest. Coast guards and forest guards are policing in the Sundarban but their activities are not enough to protect harvesters from sea pirates. Local people claimed that coast guards and forest guards are corrupt and have dealings with pirates.

6.1.5 Social capital

Table 6.6: Indicator score of social capital

No	Indicators	Matched word scenarios	Score (out of 5)
S1	Reciprocity among GO, NGO and community in mitigating risk of salinity intrusion	Different GO department and NGOs act in isolated way, Information sharing among NGOs, and among Gov. departments	2
S2	Involvement of social org, in mitigating risk of salinity intrusion	Social organizations exist but no effective activities except some ritual activities, awareness program, communicating with local government.	2
S3	Level of community initiated forest management to mitigate risk of salinity intrusion	Selective cutting, alter harvesting zone in next year, following and honoring harvesting rules of forest department,	3
S4	Livelihood assistantship program launched by gov during banning period	Gov has plan, but not implemented yet. Different NGOs persuading GOV to take initiatives,	3
S5	Political influence on social organization	Political pressure, pressure in choosing concerning issues, activities	2

The resilience status of the social capital has been analyzed following the assessment sheet through SLD. The matched scenarios of the assessment sheet are shown in the Table 6.6 with respective scores. The resilience score of the indicators range from 2-3. The score of the reciprocity is 2, that indicate low reciprocity among GO, NGO and community in mitigating salinity risk. SLDs and field observation reveals that the integration is lacking within the gov. departments. Different departments (BWDB, DOE, FD) of government are working or planning for mitigating risk of salinity intrusion in isolated ways. Different initiatives were taken to achieve integration (e.g., SBCP, ICZMP), but outcome were not effective. Different gov. departments share their knowledge and information but flow is not frequent and smooth. NGOs are working on community promotion and awareness but collaboration with government is poor. Information and knowledge sharing between NGOs and gov. departments is frequent bnt reciprocity in activities is poor. The aforementioned situations make the score of reciprocity as 2 that indicate low resilience contribution.

The resilience score of the social network is 2, which is low. Bawalis have a cooperative society named *Sundarban Banazibi Somiti* (Society of Sundarban dependent Livelihood group) which works on communicating and informing local governments about the local issues and problems. They have not worked on salinity issue but approached government throngh NGOs for their unstable livelihood opportunity in forest due to change in productivity and limiting of harvesting by forest department. Local politics plays role in recognizing problem, activities.

Resilience score of community initiated forest management to mitigate salinity risk is 3 that give moderate contribution in livelihood resilience. Bawalis are practicing altering harvesting site in response to change in productivity of the forest. Forest department encourage selective cutting while most of the harvesters do not obey the rules.

Resilience score of assistantship program is 3, which indicate moderate resilience contribution. Forest department is practicing moratorium in resources harvesting. Government has strategy to provide assistantship during banning period but has not been implemented yet. Different NGOs (e.g., Prodipon, Rupayon, etc) are working with community to facilitate other income generation activities. NGOs and local community are pursuing government to provide assistantship program for income generation, alternative livelihood opportunities during banning period.

6.2 Assessing Livelihood Resilience

The aforementioned status and performance of livelihood capitals were quantified to assess livelihood resilience by accounting the resilience score of individual indicator and its weight. Table 6.7 represents scores and weights of all indicators chosen for assessing livelihood resilience.

Table 6.7: Scores and weights of the indicators

Ind. No	Indicator	Weight	Score
	Natural capital		
N1	Propagation of salinity front	4	2
N2	Status of Sunduri typed forest	5	3
N3	Integration of river management in forest management plan	4	1
N4	Measures taken to combat salinity intrusion	4	1
N5	% of harvester follwoing the harvesting rules	5	1
N6	Spreading of top dying disease	3	2
	Total weight	25	
	Financial capital		
F1	Timber and nonwood /fish/honey production	5	2
F2	Option of non forest based livelihood	4	3
F3	Source and system of credit	4	2
F4	Support from GO/NGO in income generating activities	5	3
F5	Sudden declaration of banning harvest in Sundarban	5	3
	Total weight	23	
	Physical capital		
P1	Option of drinking water	5	3
P2	Condition of coastal embankment/polders	4	3
P3	Failure coastal embankment (How often)	3	2
	Total weight	12	
	Human capital		
H1	Knowledge on non forest dependent livelihood	4	4
H2	Knowledge on climate change	3	3
H3	Level of adaption mechanism	4	3
H4	Attack of Royal Bengal Tiger	3	2
H5	Attack of sea pirates	5	2
	Total Weight	19	
	Social capital		
S1	Reciprocity among GO, NGO and community in mitigating risk of salinity intrusion	5	2
S2	Involvement of social org, in mitigating risk of salinity intrusion	3	2
S3	Level of community initiated forest management to mitigate risk of salinity intrusion	3	3
S4	Livelihood assistantship program launched by gov during banning period	5	3
S5	Political influence on social organization	3	2
	Total weight	19	

The livelihood resilience of the Bawali has been assessed by following the equation 3.1-3.6 of chapter three. The detail calculation is given in the Appendix V. The livelihood resilience of the Bawali is 47.6 in the scale of 100 where resilience of natural, financial, physical, human and social capitals are; 33.6, 52.2, 55.0, 55.8 and 48.4 respectively in the scale of 100 (Table 6.8).

Table 6.8: Livelihood resilience of Bawali

Livelihood Capital	Total weight (from Table 6.7)	Resilience		Word Scenario
		in scale of 100	in scale of 5	
Natural capital	25	33.6	1.7	Poor
Financial capital	23	52.2	2.6	Low
Physical capital	12	55.0	2.8	Low
Human capital	19	55.8	2.8	Low
Social capital	19	48.4	2.4	Low
Livelihood resilience		**47.8**	**2.4**	low

The result shows that the contribution of natural capital on livelihood resilience is poor (33.6%) while the total weight of the natural capital is highest (25). The resilience status of financial, physical, human and social capitals are low. As the livelihood resilience is the networked capacity of the livelihood capitals, low resilience status of the livelihood capitals makes the livelihood resilience of Bawali low (47.8). In Figure 6.1 the livelihood resilience of Bawali is delineated according to numeric and qualitative scale (according to the word scenarios of the assessment sheet).

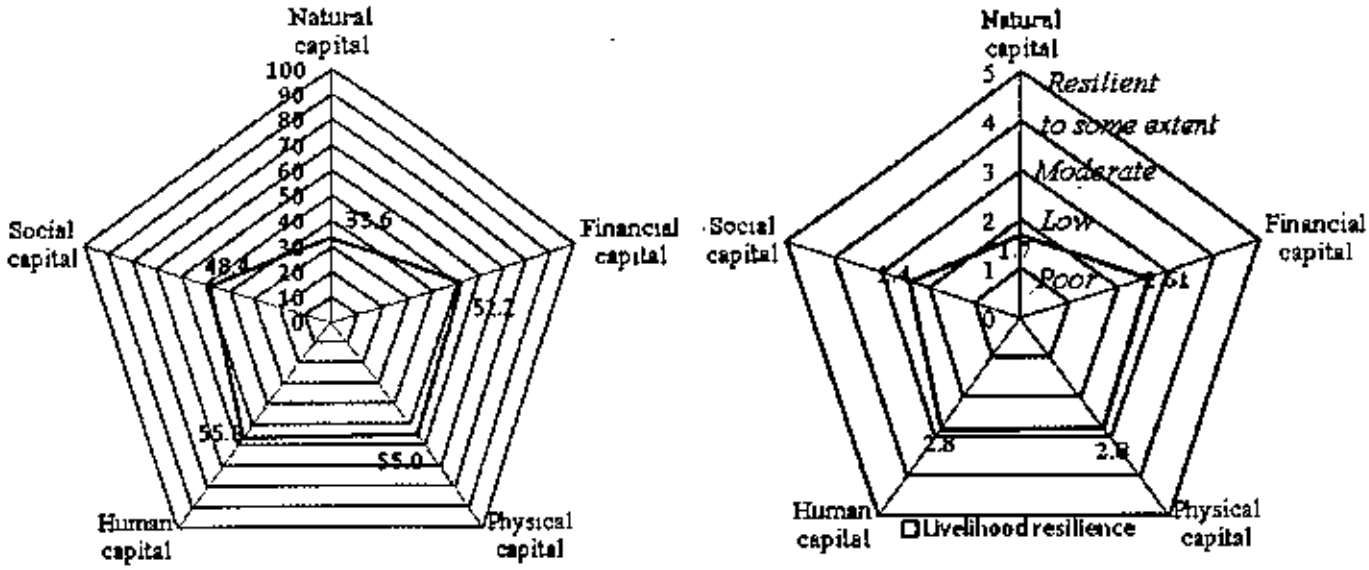

Figure 6.1: Livelihood resilience of Bawali

The rights diagram of Figure 6.1 shows the spider diagram of the livelihood resilience in scale of 100 which was directly quantified from the algebraic transformation of the participatory livelihood resilience model (Equation 3.1-3.6). And the left diagram of Figure 6.1 shows the livelihood resilience in qualitative scale where the resilience of individual livelihood capital has been converted from scale of 100 to scale of 5 to match the word scenarios.

It is seen from the Table 6.8 and Figure 6.1 that the importance and resilience contribution of different livelihood capitals are different. They give a sense of strategic action in response to climate change induced salinity intrusion: where we should take policy interventions, which domain of livelihood capital requires prioritization. The resilience analysis followed by indicator framework has disclosed directives of capital based adaptation strategy to build the livelihood resilience to climate change induced salinity intrusion.

6.3 Capital Based Adaptation Strategy

Resilience analysis explores possible adaptation measures that needed to be incorporated in to the adaptation policy. Capital based approach offers proper understanding of communities' weakness, strength and opportunities that help to avoid unnecessary intervention. Capital based approach of adaptation strategy reflects the local people perception. Resilience analysis of the Bawali in capital based approach explores the following elements of adaptation strategy.

Fostering natural capital management: incorporation of river management plan in forest management, reciprocity among governments departments, and co-management of forest resources

Enhancing the resilience of natural capital requires incorporation of river management plan in forest management plan. The forest resiliency to salinity relies on the river management and fresh water flow augmentation (Wahid et al., 2007; IWM, 2007; CEGIS, 2006; Huq 2002). Integration of work of BWDB, DOE, DOF, FD in mitigating risk of salinity intrusion will result effective forest management and monitoring.

The sustainability and effectiveness of the forest management is pinned with co-management that means, incorporation of local knowledge, and participation of the resource extractor and other stakeholders at all level of resources management process (Islam and Wahab, 2005). This participation is already been realized in our forest policy (Iftekhar and Islam, 2004) but not implemented in the practical field.

Modeling for optimizing extractable resources

A decision making model should be developed incorporating local knowledge to estimate optimum extractable resources. Current practice is that, the station officer pre-

estimate the extractable resources roughly based on own observation and judgment before harvesting season. This process could be done through decision making model based on forest sustainability and insights of livelihood groups. This approach will enhance the sustainable harvesting, forest comanagement and adaptive governance of the forest as well as resilience of the natural capital.

Developing financial capitals: diversification of livelihood opportunities

Resilience of the financial capital depends on diversification of the livelihood opportunities and income sources from non forest dependent livelihood options, while the ecological health status of the forest is deteriorating due to salinity intrusion. Resilience analysis reveals potential non forest dependent livelihood options that could be the good means of living of the Bawali. Government facilitation will help the Bawalis to sustain these income generation options. Different NGOs are working on promoting non forest dependent livelihood options, but inadequately. In Table 6.9 the potential local enterprises and Bawalis' asking facilities are shown.

Table 6.9: Potential income generation enterprises of Bawalis

Potential Income generation enterprise	Bawalis' asking facilities form government
Mat making	Financial
Vegetable cultivation	Financial
Water melon cultivation	Financial
Timber sawing	Financial
Poultry farming	Financial and technical
Livestock raring	Financial and technical
Culture fisheries	Financial and technical
Road side vegetation cultivation	Financial
Van pulling	Financial

Different loan/fund scheme for small enterprise should be availed to Sundarban dependent livelihood group with flexible condition.

Development and management of physical capital: Option of safe drinking water and Comanagement of embankments and legal act to protect illegal breaches

Option of safe drinking water which is not susceptible to salinity intrusion gives resilience. According to Bawali community, rain water harvesting system in each household will be the resilient source of drinking water. Technical facilitation of the management committees of the community ponds and PSF will enhance the management practices of the existing drinking water facilities.

Controlling illegal breaches on the embankment will mitigate the risk of embankment failure. Community based management of polders and adopting legal action will control the act of illegal breaching.

Enhance human capital: awareness and training program on possible impact of climate change, on non forest dependent livelihood opportunities

Awareness growing is always a good means of understanding and mitigating risk. Awareness on possible impact of climate change and knowledge on non forest dependent livelihood options strengthen the human capitals. Training and skill development of the forest dependent community on other non forest dependent livelihood activities makes them resilient to productivity change of Sundarban due to climate change induced salinity intrusion. In this case, government shonld provide facilities on the enterprises which have potentiality of sustainable income. Table 6.9 provides some potential enterprises practicing in the community which reqnire facilitation to become sustainable.

Community monitoring with facilitation of forest department could be done to control incident of tiger attack. Local people practices strong fence and living fence of plants having spines (cactus) around the house. Community watch tower along the forest border will help them to patrol. Freshwater reservoir could be made in forest area to provide fresh water to wildlife. Government and NGOs provide compensation for affected family which should be enhanced. Forest department also insists resource extractor to have insurance before entering the forest. This practice should be adopted widely. Community awareness should be developed. Awareness and training program for resource extractor will help them to avoid risk during forest resource harvesting.

Value social capital: strengthen social organization and enhance social network

The livelihoods groups of Sundarban should be assisted through enhancing safety nets. During moratorium periods, government should assist them by work facilitation program. Reciprocity between existing social organization (e.g., Sundarban Banojihi Somity) and forest department should be enhanced. Awareness should be grown about the climate change impact and fate of the Sundarban to adopt livelihood diversification and to reduce forest dependency.

CHAPTER SEVEN

CONCLUSION AND RECOMMENDATION

7.1 Conclusion

The participatory model for assessing livelihood resilience developed in this study describes the resilience as a set of networked capacities of livelihood capitals. The model is based on indicator framework consists of 24 indicators. This framework is reflective of local people perception. The indicators were selected from three dimensions; i) productivity, ii) sustainability and iii) risk that describe the both dynamic and static attributes of the livelihood resilience. The framework is structured into five livelihood capitals i.e., natural, financial, physical, human and social

According to importance, indicators for natural capital are: status of Sunduri typed forest, % of harvester following the harvesting rules, propagation of salinity front, integration of river management plan in forest management plan, measures taken to combat salinity intrusion, and spreading of top dying diseases.

Indicators for financial capital, according to importance are: forest production, support from GO and NGO, banning of harvesting, non forest based livelihood option, and source and system of credit.

According to importance, indicators for human capital are: attack of sea pirates, knowledge on non forest dependent livelihood, level of adopting coping mechanism, knowledge on climate change, and attack of tiger.

According to importance, indicators selected for physical capital are: option of drinking water, condition of coastal embankments and failure of coastal embankment.

And for social capital, selected indicators according to importance are: reciprocity, assistantship program, involvement of social organization, level of community forest initiated management and political influence.

The indicator framework was employed to assess livelihood resilience of Bawali to climate change induced salinity intrusion. The livelihood resilience of Bawali is 47.8 % that indicates low resilience. The resilience contribution of natural, financial, physical, human and social capitals are. 33.6%, 52.2%, 55%, 55.8% and 48.4%, while their total

weights are 25, 23, 12, 19 and 19 respectively. Among the five livelihood capitals, contribution of natural capital to livelihood resilience is lowest while the weight is highest. Poor forest management practices and deteriorating health status of forest have made the resilience of natural capital poorer. Similarly low income form forest and poor support from GO and NGOs have reduced the resilience contribution of financial capital. Risk of failure of embankment due to illegal breaches has reduced the resilience contribution of physical capital. High risk of occupational hazard (attack of tiger and sea pirates) has made the resilience contribution of human capital low. Poor reciprocity among GO, NGOs, and communities; weak social network and political influence on social organization have reduced the resilience contribution of social capital.

7.2 Recommendation

The conceptual basis, resilience score and weight of the individual capital give directive of asset based adaptation strategy to climate change induced salinity intrusion. The key elements that should be considered in adaptive governance of the Sundarban socioecologial system are;

- Fostering natural capital management: incorporation of river management plan in forest management, reciprocity among governments departments, and co-management of forest resources.
- Modeling for optimizing extractable resources.
- Developing financial capitals: diversification of livelihood opportunities.
- Development and management of physical capital: option of safe drinking water, comanagement of embankments and legal act to protect illegal breaches.
- Enhancement of human capital: awareness and traiuing program on non forest dependent livelihood opportunities.
- Valuation social capital: strengthening social organization and enhancement of social network.

7.3 Further Study

- Area variation of livelihood resilience was not considered in the study. A further study could be done on livelihood resilience of east and west zone, and different salinity zone of the Sundarban.
- Resilience analysis of other livelihood group particularly, fisher and Mawali should be done.
- This study only gives a directive of adaptation strategy. A further study could be conducted on details adaptation strategy of adaptive governance of the Sundarban socio-ecological system which will be amenable to area variation of livelihood resilience, resilience of all livelihood gronps, and all threats of climate change.

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APPENDIX I

PRELIMINARY CHOSEN INDICATOR FRAMEWORK BASED ON LITERATURE REVIEW

Natural capital		
Dimension	**Criteria**	**Indicator**
Productivity	Forest health status	Propagation of salinity front
		Percentage of Sunduri typed forest
Sustainability	Effectiveness of river Management in Sundarban	Integration of river management in forest management plan
		Measures taken to combat salinity intrusion
	Effectiveness of forest management	Corruption of forest department staff
		Improvement of forest health
		Production increase
		% of Harvesters follows harvesting rules
Risks	Corruption in the process of getting harvesting permits	Taka needed to bribe for each permit (Proportion to legal amount)
	Pressure on forest	Spreading of top dying disease
		No of incident of forest fire by human
		No of incident of use of poison for fishing
Total: 3	5	12
Financial capital		
Productivity	Income productivity	Portion of HH expenditure managed by income from forest
	Credit system	Source and system of credit
		Strictness of MFI's rules
	Degree of diversification of livelihood	Scope of alternative job
		% of Population have own agricultural land, fisheries pond, etc
Sustainability	Stability of income generating activities	Availability of information on future climatic stress
		Access to early warning system during trip to Sundarban
	Dependency on natural resource	Portion of HH income earned from forest
	Assistantships from GO\NGO for livelihood diversification	Support from GO\NGO for income generating activities
		% population have training
Risks	Instability of government approach towards their livelihood	Banning of harvesting in Sundarban
		Risk of sudden closing of assistantship program
Total: 3	7	12

APPENDIX I

PRELIMINARY CHOSEN INDICATOR FRAMEWORK BASED ON LITERATURE REVIEW (CONTINUED)

Human capital		
Dimension	**Criteria**	**Indicator**
Productivity	Training and education	Training program launched each years
		% population having training
		% of population having primary education
		Rate of school Enrolment
	State of health services	Serving population ratio-doctor (population per doctor)
		Distance of hospital
Sustainability	Level of environmental awareness and knowledge on climate change risk	Knowledge on climate change
		awareness program launched in the community each year
		Level of adopted coping mechanism
Risks	Out migration of skilled manpower	Rate of out migration of skilled people (%)
	Occupational hazard	Attack of Royal Bengal Tiger
		Attack of sea pirates
Total: 3	5	12
Physical capital		
Productivity	Protection to natural disaster	% of Population have own house
		% population inside the polder
		Housing condition
	Fresh water resources	Option for drinking water
		Distance to nearest safe fresh water source
		Efficiency of management practices
	Transportation and communication	Condition and performance of navigation services (Buoys, lights, markers, pontoon)
		Remoteness from district (time required to reach district city)
		Availability of paved road
		% of household have cellular/land phone
Sustainability	Disaster management	Effectiveness and performance of local disaster management committee
Risk	Failure of coastal structure	How frequent
Total: 3	5	12
Social capital		
Productivity	Institutional structure	Interrelation between GO and community
		Interrelationship between NGO and community
	Social network	Existence of social organization of livelihood groups
		Function of that group
		Linkage of family network
Sustainability	Safety nets	Livelihood assistantship program by govt during moratorium
		Assistantship in diversifying livelihood
	Effectiveness of GO, NGO or other social network	Training program relevant to livelihood launched by GO/NGOs
		Awarencss program launched by GOs/ NGOs per year
		Percent of HH have implement those knowledge
Risks	Local politics	Political influence on social group/ committee
Total: 3	5	12

APPENDIX II

SCREENED INDICATOR FRAMEWORK AFTER SLD

Natural Capital		
Dimension	**Dimension Criteria**	**Indicator**
Productivity	Forest health status	Propagation of salinity front
		Status Sunduri and Gewa typed forest
Sustainability	Effectiveness of forest management plan to combat salinity intrusion	Integration of river management in forest management plan
		Measures taken to combat salinity intrusion
		Community Participation
		% of harvester follows harvesting rules
Risks	Corruption	Corruption of forest department staff
	Pressure on Forest	Spreading of top dying disease
		No of incident of use of poison for fishing
Total: 3	4	9
Financial Capital		
Productivity	State of forest production	Wood production (sunduri, goran)/ Non wood product (Nypa, Mele grass)/ Fish production/ Honey production
	Degree of diversification of livelihood	Access to non forest based livelihood options
	Credit System	Source and system of Credit
Sustainability	Dependency on natural resource	Portion of HH income earned from forest
	Support from GO\NGO for livelihood diversification	Support from GO\NGO for income generating activities
Risks	Instability of Government approach towards their livelihood	Banning of Harvesting in Sundarban
Total: 3	6	6

APPENDIX II

SCREENED INDICATOR FRAMEWORK AFTER SLD (CONTINUED)

Human		
Dimension	**Criteria**	**Indicator**
Productivity	Training and Education	State of training Program
		% of population having primary Education
Sustainability	Local understanding of Risk	Knowledge on Climate Change
		Level of coping mechanism to adapt with salinity intrusion
Risks	Occupational Hazard	Attack of Royal Bengal Tiger
		Attack of Sea pirates
Total: 3	5	6
Physical		
Productivity	Fresh water Resources	Option for drinking water
		Distance to nearest safe fresh water source
	Transportation and Communication	Remoteness from District (Time required to reach district city)
		Availability of paved road
Sustainability	Coastal defense structure to protect salinity intrusion	Condition of embankments
Risk	Failure of Coastal Structure	How frequent
Total: 3	2	6
	Social Capital	
Productivity	Institutional Structure	Interrelation between GO and community
		Interrelationship Between NGO and Community
	Social network	Status of social organization (society) of Livelihood Groups
Sustainability	Livelihood group initiated forest management to combat salinity intrusion	Level of practicing management
	Safety Nets	Livelihood Assistantship program by Govt during banning period
Risks	Local Politics	Political influence on social group/ committee
Total: 3	5	6

APPENDIX III

FINAL INDICATOR FRAMEWORK FOR ASSESSING LIVELIHOOD RESILIENCE

Dimension	Criterion	Indicator
Natural capital		
Productivity	Forest health status	Propagation of salinity front
		Status of Sunduri typed forest
Sustainability	Effectiveness of forest management plan to combat salinity intrusion	Integration of river management in forest management plan
		Measures taken to combat salinity intrusion
		% of harvester follwoing the harvesting rules
Risk	Pressure on forest	Spreading of top dying disease
Financial capital		
Productivity	State of forest production	Timber and nonwood/fish/honey production
	Degree of livelihood diversification	Having options of non forest based livelihood
	Credit system	Source and system of credit
Sustainability	Support from GO and NGO	Support from GO/NGO in income generating activities
Risk	Instability of govt approach	Sudden declaration of banning harvest in Sundarban
Human capital		
Productivity	Knowledge	Knowledge on non forest dependent livelihood
Sustainability	Local understanding of risk	Knowledge on climate change
		Level of adopted coping mechanism
Risk	Occupational hazzards	Attack of Royal Bengal Tiger
		Attack of sea pirates

APPENDIX III

FINAL INDICATOR FRAMEWORK FOR ASSESSING LIVELIHOOD RESILIENCE (CONTINUED)

Dimension	Criterion	Indicator
Physical capital		
Productivity	Drinking water resources	Option of drinking water
Sustainability	Coastal defence strusture to combat salinity intrusion	Condition of coastal embankment/polders
Risk	Failure of coastal defence structure	Failure of coastal embankment (How often)
Social capital		
Productivity	Reciprocity	Reciprocity among GO, NGO and community in mitigating risk of salinity intrusion
	Social network	Involvement of social org, in mitigating risk of salinity intrusion
Sustainability	Community initiated forest management in response to salinity intrusion	Level of community initiated forest management to mitigate risk of salinity intrusion
		Livelihood assistantship program launched by gov during banning period
Risk	Local politics	Political influence on social organization

APPENDIX IV

ASSESSMENT SHEET CONSISTS OF WORD SCENARIOS

Indicator	Word scenarios: worst case to best case; score 1-5				
	Worst case score: 1	2	3	4	Best case score: 5
Natural capital					
Propagation of salinity front	Salinity have affected in the zone of Mele pata forest (fresh water zone)	Salinity have affected in the zone of Sunduri forest	Salinity have in the zone of Goran forest	Salinity has been increasing but forest production has not been affected yet.	No change over last 5 years
Status of Sunduri typed forest	Sunduri typed forest drastically reduced and Goran typed forest dominates. No Sunduri type forest in Moderate saline zone	Sunduri typed forest is dominating but soon it will not be dominating due to multi-stress of salinity intrusion; forest health is detritus in moderate saline zone.	Salinity intrusion is affecting the Sunduri tree, height has been reduced, in fresh water zone, In moderate saline zone Sunduri typed forest is shrinking	Forest health is good, but soon it will be affected by salinity intrusion.	Ecologically healthy
Integration of river management in forest management plan	Not mentioned in plan	Only mentioned but not thoroughly	Fully considered but not implemented	Considered and partially implemented	Successfully Implemented
Measures taken to combat salinity intrusion	Not mentioned in plan	Only mentioned but not thoroughly	Fully considered but not implemented	Considered and partially implemented	Successfully Implemented
% of harvester follwoing the harvesting rules	No or few (10-20%) are following	20-40%	Good portion (40-60%)	Large population (60-80)	All or near all (80-100%)
Spreading of top dying disease	Disease has spread over the entire area of forest as like as epidemic	Disease affects moderate and high saline zone. Some parts of fresh water zone is also affected	Disease affects moderate and high saline zone	Only High saline zone	No or rare

APPENDIX IV

ASSESSMENT SHEET CONSISTS OF WORD SCENARIOS (CONTINUED)

Indicator	Word scenarios: worst case to best case; score 1-5				
	Worst case score: 1	2	3	4	Best case score: 5
Financial capital					
Timber and nonwood /fish/honey production	Very few production that provide house hold expenditure for few months (1/2 months)	Small production that provide HH expenditure for 3-5 months	Fare production that provide HH expenditure for months 6-8	Good production that provide HH expenditure for 8-10 months	Better production that provide HH expenditure for more then 10 months
Option of non forest based livelihood	No option of NFL /migrate to the city for livelihood option	Having option of daily labor for a particular seasons, wood chopping for firewood	Agricultural labor, option of daily labor round the year (or at least 8 months)/pulling van in local areas.	Have own agricultural land, seasonal business. These provide HH expenditure for at least 8 months	Column, seasonal business. These provide HH expenditure for more then 8 months
Source and system of credit	No credit source	Mohajon (local Money Lender) with condition: "Have to sell product to Mohajon at price fixed by Mohajon"	Mohajon With medium interest and no such condition as mentioned in column 2.	Mohajon with low – medium interest. MFIs, Gov Banks	From Relatives/ others without any Interest
Support from GO/NGO in income generating activities	No support from gov/NGO	Insignificant and inequitable support. Heard that GOC/NGOs have plan-program but not get yet	Only financial/technical support, inadequate	Both financial and technical support adequate in some extent	Enough technical and financial support
Sudden declaration of banning harvest in Sundarban	Frequently and without any reason, and without any notice	Frequently after event like cyclone and epidemic	Frequently after high magnitude cyclone like Sidr, epidemic	After high magnitude cyclone, epidemic. Not entire forest but only affected compartments were closed to harvest	Never

APPENDIX IV

ASSESSMENT SHEET CONSISTS OF WORD SCENARIOS (CONTINUED)

Indicator	Word scenarios: worst case to best case; score 1-5				
	Worst case score: 1	2	3	4	Best case score: 5
Human capital					
Knowledge on non forest dependent livelihood	Don't have any skill on other non forest dependent livelihood	Know only wood chopping. And earthen works (digging, loading)/ van pulling	Wood chopping, house repairing, fencing, agricultural works,	Local works like column 3, seasonal trading business of agricultural products, and some knowledge on building construction, boat making,	Have trained/ good skill on works like column 3, shrimp farming, apiculture
Knowledge on climate change	Know nothing	Only Heard, don't remember how they know it.	Know but not clear. Heard from NGOs. Have heard about SLR and Inundation,	Know Well about CC impact. Have got awareness program, by NGOs/GO . Heard about CC and its possible impact	Know well, know about CC and its impact on Sundarban. Got awareness program, training. Have Preparation/ Adaptation
Level of adaption mechanism	No adaption mechanism	Adaptation only for income generation, harvesting multiple resources	decreasing dependency on forest resource by diversifying livelihood, saving,	Column 3, obeying GOV harvesting rules responding to salinity intrusion,	GOV supported community based forest management to mitigating risk of salinity intrusion, selective cutting,
Attack of Royal Bengal Tiger	Tiger enters settlements and harvester's boats frequently. Rate of attack has been increased in fresh water zone.	In fresh water zone incident of tiger attack is increasing, and has increased in moderate saline zone	In fresh water zone incident rare or 1-2 times per year, High in moderate saline zone	No incident is recorded in fresh water zone. while 1-2 times in moderate water zones.	Rare. And Gov has taken proper initiatives to control future incidents by availing fresh water sources in moderate and high saline zones
Attack of sea pirates	Several times by different groups at each harvesting trip, causing health hazards and took away all things, no security force	Several times by different groups at each harvesting trip. There is a rule of giving fixed amount of money to each of the groups. Have security force but not active/adequate	Not every trip, its happens randomly, having option of negotiation by giving certain amount of money, having security forces : partially active	Have risk of attack but gov security forces (coastal guard, forest guard) are very active	No risk of sea pirates, Moreover gov security guards are very active

APPENDIX IV

ASSESSMENT SHEET CONSISTS OF WORD SCENARIOS (CONTINUED)

Indicator	Word scenarios: worst case to best case; score 1-5				
	Worst case score: 1	2	3	4	Best case score: 5
Physical capital					
Option of drinking water	River/ canal/ Seasonal water body/	Large pond, Shallow tube well susceptible to As contamination, expected to be saline due to salinity intrusion	Deep tube well, Pond with PSF (within village) Poor operation and management	Rain water supply system, pond with PSF (within community),	Pipe water supply system/ other community water supply system resilient to salinity intrusion, Gov facilitated artificial recharge (RW harvesting) to protect GW from salinity.
Condition of coastal embankment/polders	No polder, or have levee where overtopping is common during high tide	Polder exists. But shrimp cultivators frequently make illegal breaches in polder at several points, overtopping during spring tide	Polder exist but management is poor, have illegal breaches in some places, will not retain during cyclonic event	Polder with good management committee, overtopping of water during cyclonic event	Sea dyke, better management committee, rare chances of over topping, again having option of quick drain out facilities
Failure of coastal embankment (How often)	Frequently collapse/ over topped, each year (1-2 year) during spring tide, monsoon cyclone	After every 2/3 years,	Frequency is around 5 years	After 5-10	Above 10 years

APPENDIX IV

ASSESSMENT SHEET CONSISTS OF WORD SCENARIOS (CONTINUED)

Indicator	Word scenarios: worst case to best case; score 1-5				
	Worst case score: 1	2	3	4	Best case score: 5
Social capital					
Reciprocity among GO, NGO and community in mitigating risk of salinity intrusion	No collaboration, reciprocity among goc departments and between GO and NGOs,	Different gov department and NGOs act in isolated way, Information sharing among NGOs, and among GO departments	Partnership building, information and knowledge sharing, But not act in integrated way, but collaboration in growing	Information sharing among and between gov and NGOs. Knowledge sharing. In some extent they act in integrated way,	Integration among gov departments and with NGOS.
Involvement of social org, in mitigating risk of salinity intrusion	No such social organization	Social organizations exist but no effective activities except some ritual activities, awareness program, communicating with local government.	Organizations do awareness program, community promotion, co-operation, communicating with local government in context of local issues, problem	Organizations do effective act on awareness program, cause analysis, planning in response to changing scenarios, fund raising	Effectively act on adaptation, risk mitigation, knowledge generation, communication with gov for technical facilities,
Level of community initiated forest management to mitigate risk of salinity intrusion	No such activities, thinking this is on hand of forest department not community	Award about the problem,	Selective cutting, alter harvesting zone in next year, following and honoring harvesting rules of forest department,	Harvesting zoning, define sustainable harvesting rules collaborating with forest department,	Forest comanagement, risk zoning, monitoring harvesting in forest, monitoring forest health and report to forest department.
Livelihood assistantship program launched by gov during banning period	No such program	Gov has plan, but not implemented yet. Different NGOs persuading GOV to take initiatives.	Food assistantship program, Medical assistantship program, Food for work program especially designed for this livelihood group	Alternative income generation program, Gov. provide technical and financial facilities,	Column 4 plus, Gov promote alternative income generation option
Political influence on social organization	Political pressure, political shaping of social organization, political shaping of organizational body	Political pressure, pressure in choosing concerning issues, activities	Political shaping of organizational body but no pressure on activities	No political pressure, No political shaping	Column 4. Political collaboration to act effectively, no political pressure

APPENDIX V

CALCULATION SHEET: LIVELIHOOD RESILIENCE ASSESSMENT

Ind. No	Indicator	Weight	Score	W*I
Natural capital				
N1	Propagation of salinity front	4	2	15
N2	Status of Sunduri typed forest	5	3	4
N3	Integration of river management in forest management plan	4	1	4
N4	Measures taken to combat salinity intrusion	4	1	5
N5	% of harvester follwoing the harvesting rules	5	1	6
N6	Spreading of top dying disease	3	2	42
	Total	**25**		
Resilience (in scale of 100) according to equation 2.2		33.6		
Financial capital				
F1	Timber and nonwood /fish/honey production	5	2	10
F2	Option of non forest based livelihood	4	3	12
F3	Source and system of credit	4	2	8
F4	Support from GO/NGO in income generating activities	5	3	15
F5	Sudden declaration of banning harvest in Sundarban	5	3	15
	Total	**23**		60
Resilience (in scale of 100) according to equation 2.3		**52.2**		
Physical capital				
P1	Option of drinking water	5	3	15
P2	Condition of coastal embankment/polders	4	3	12
P3	Failuring coastal embankment (How often)	3	2	6
	Total	**12**		33
Resilience(in scale of 100) according to equation 2.4		**55**		

Table 1: Quantifying resilience contribution of individual livelihood capital

APPENDIX V

CALCULATION SHEET: LIVELIHOOD RESILIENCE ASSESSMENT (CONTINUED)

Table 1: Quantifying resilience contribution of individual livelihood capital (continued)

Ind. No	Indicator	Weight	Score	W*I
Human capital				
H1	Knowledge on non forest dependent livelihood	4	4	16
H2	Knowledge on climate change	3	3	9
H3	Level of adaption mechanism	4	3	12
H4	Attack of Royal Bengal Tiger	3	2	6
H5	Attack of sea pirates	5	2	10
	Total	**19**		53
Resilience(in scale of 100) according to equation 2.5		**55.8**		
Social capital				
S1	Reciprocity among GO, NGO and community in mitigating risk of salinity intrusion	5	2	10
S2	Involvement of social org, in mitigating risk of salinity intrusion	3	2	6
S3	Level of community initiated forest management to mitigate risk of salinity intrusion	3	3	9
S4	Livelihood assistantship program launched by gov during banning period	5	3	15
S5	Political influence on social organization	3	2	6
	Total	**19**		46
Resilience (in scale of 100) according to equation 2.6		**48.4**		

APPENDIX V

CALCULATION SHEET: LIVELIHOOD RESILIENCE ASSESSMENT (CONTINUED)

Table 2: Quantifying livelihood resilience

Livelihood capital	**Resilience score,** $R_{N/F/P/H/S}$	**Total weight of the capital,** $W_{tN/F/P/H/S}$	**R*W**
Natural capital	33.6	25	840
Financial capital	52.2	23	1200
Physical capital	55.0	12	660
Human capital	55.8	19	1060
Social capital	48.4	19	920
Total			4680
Livelihood resilience (in scale of 100) according to equation 2.1			**47.8**

APPENDIX VI

PICTURES OF LEARNING MEETINGS OF SLD

Figure: Learning meeting in Amadi during first field visit

Figure: Learning meeting in 4 no Kovra during first field visit

Figure: Learning meetin in Amadi during secon field visit